GUIDE BOOK No. 7

EXCURSIONS

TO

Sudbury, Cobalt and Porcupine

(EXCURSIONS A 3 and C 6)

ISSUED BY THE ONTARIO BUREAU OF MINES, TORONTO

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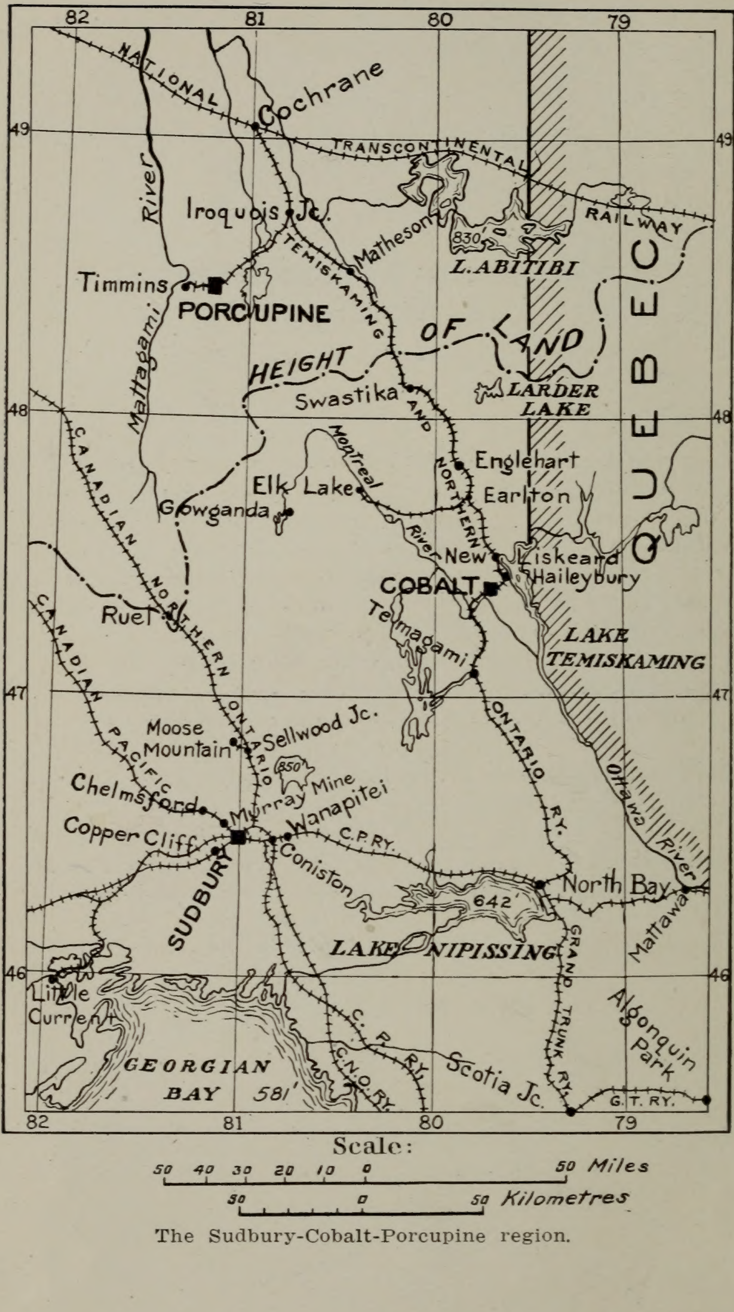

The Sudbury-Cobalt-Porcupine region.

PREFACE.

The three mining areas, viz.: Sudbury, Cobalt, and Porcupine, that are described in this Guide Book, are the most important in the Province of Ontario. Sudbury is the world's greatest producer of nickel and is also an important producer of copper. Minor quantities of platinum, palladium and other metals have been obtained from its ores. Cobalt leads all other areas in the world in its output of silver and of cobalt, and arsenic and nickel occur in important quantities in its ores. Porcupine, the product of which is gold, is a comparatively new mining area and is only partly developed. The two chief mines, however, are splendidly equipped, and during the last year have been important producers. Other mines at Porcupine have recently begun milling operations.

As nearly as can be determined from Government reports, Sudbury had produced, in round numbers, 158,000 tons of nickel and 103,000 tons of copper by the end of 1912. Statistics of by-products—platinum, palladium, and other metals—are incomplete. At the same date, cobalt had produced approximately 156,000,000 ounces of silver. In 1912, owing to the Porcupine production, the gold output of Ontario had a value of $1,859,285, compared with $42,637 in 1911.

The ore deposits of all three of the areas are in rocks that are classified as of pre-Cambrian age, and are believed to owe their origin to igneous intrusions. At Sudbury the intrusive rock, described on following pages, is quartz-norite, at Cobalt quartz-diabase, and at Porcupine granite.

Sudbury is about 90 miles to the southwest of Cobalt, and it is believed that the norite of the one area and the quartz-diabase of the other are genetically connected. The close chemical relations of the two rocks are described in the following pages devoted to the Cobalt area.

The colored geological map, on a scale of eight miles to the inch, that accompanies this guide book, shows the geology of the three areas in so far as it is at present known. Larger scale maps have been published and are referred to in the text.

Relations of the Rocks.

Keewatin Series.

As the legend on the map shows, the oldest series known in the region is called the Keewatin. It consists for the greater part of basic volcanic rocks, now represented by schists and greenstones, together with more acid varieties such as quartz-porphyry. Associated with the Keewatin is considerable sedimentary material, consisting of schistose greywacké, jaspilyte, or iron formation, and crystalline limestone, which is, however, not seen in large exposures in any of the three mining areas. These sedimentary rocks are believed to represent the Grenville series of southeastern Ontario.

Laurentian Granite and Gneiss.

The rocks next younger than the Keewatin are grey granite and gneiss. They are well exposed along the railway north of North Bay, and are called Laurentian.

Temiskaming Series.

After the intrusion of the Laurentian into the Keewatin, there was a prolonged period of erosion, during which a thick series of sediments consisting of conglomerate, greywacké and other rocks was deposited. To this series in the Cobalt and Porcupine areas the name Temiskaming has been given. It is known in other areas to the north, south and west of Cobalt and appears to be represented at Sudbury by what Dr. Coleman has called the Sudbury series.

Lorrain Granite.

After the deposition of the Temiskaming sediments an intrusion of granite, characteristically pink in color, took place. This granite, which occupies large areas, is known as Lorrain. The relations of this granite to both the older and younger rocks are clearly shown at Cobalt. The granite which gave rise to the gold deposits at Porcupine appears to be of the same age.

Cobalt Series.

The period of erosion that succeeded the intrusion of the Lorrain granite gave rise to the conglomerate and other rocks known as the Cobalt series. Good exposures of these rocks are to be seen at Cobalt and along the railway to the south and to the north. At Porcupine only small exposures are found. The Ramsay Lake conglomerate of Sudbury appears to be of the same age.

In the Sudbury area there is also a series of sediments which has been mapped as of Animikie age. The age relation of this series to the Cobalt series and to the Ramsay Lake conglomerate is not definitely known.

Nipissing Diabase and Sudbury Norite.

Succeeding the deposition of the Cobalt series came the intrusion of the quartz-diabase which gave rise to the silver deposits of Cobalt. This intrusive is known as the Nipissing diabase. As stated above, the Sudbury norite, with which are genetically connected the nickel-copper deposits, is similar in chemical composition and appears to be of the same age.

Paleozoic Rocks.

To the north and east of Cobalt, limestone, with basal conglomerate and sandstone, of Silurian (Niagara) age, occurs as outliers on the pre-Cambrian.

With the exception of deposits of glacial and recent age, no rocks younger than the pre-Cambrian are found in the vicinity of Sudbury or Porcupine.

W. G. M.

Toronto, June, 1913.

THE SUDBURY AREA

BY

A. P. COLEMAN.

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INTRODUCTION.

The Sudbury region is especially known for its nickel mines, the most important in the world; but the geologist finds an almost equal interest in its eruptive rocks, which include a remarkable basin-shaped laccolithic sill more than a mile thick and covering 400 square miles of territory, and its unusually complete set of pre-Cambrian formations, probably not surpassed by any other area of equal size in America. The region displays also striated rock surfaces and boulder clay, due to Pleistocene glaciers and shore and deeper water deposits of ancient Lake Algonquin.

The scenery of the region is mostly of the "rocky lake" character, but this is diversified with considerable stretches of fertile farm lands. In many parts the original forest has been destroyed by the lumberman and by fire, leaving the rock hills bare, so that the geological structures are admirably exposed; and in a few places sulphur fumes from roast beds and smelters have destroyed all vegetation, allowing rain to carve the drift materials and expose the glacier smoothed rock surfaces beneath.

The most striking physiographic features of the region are connected with the great basin-shaped sheet of the nickel eruptive. This consists of an easily-weathered outer side of norite blending into a resistant inner side of a granitic character, whch has metamorphosed and hardened the rocks above; so that after passing the irregular Archæan surface which surrounds the basin, there is everywhere a depression or trough, sometimes occupied by lakes, representing the basic portion of the eruptive, followed after a mile or two by rugged hills, made up of the acid portion and the metamorphosed sediments above.

After crossing this belt of rough hills the interior spreads out as a low plain covered with old lake deposits, often level as a prairie. From the farms of the interior one sees the rim of the basin rising on all sides as ridges or hills sometimes reaching 500 feet above the sheltered plain. The basin is drained by Vermilion river and its tributaries, which descend as fine cataracts and falls when their course leads over the acid edge, or meander with a gentle current

Rain erosion and striated surface of greywacké, Copper Cliff.

through the old lake deposits of the interior. The spreading out of the sheet of molten rock and its settling into a synclinal basin have given a regularity to the topographic forms not found in other pre-Cambrian regions, and rivers and lakes and farms and railway routes are all adjusted to the ancient rock structures.

Sudbury itself, the capital town of the region, lies some miles southeast of the edge of the basin and rests upon older rocks with a less orderly arrangement. They include near Wanup and Quartz on the Canadian Pacific and Canadian Northern railways, characteristc rocks of the Grenville Series, whose position with reference to the classification adopted by the International Committee is somewhat uncertain; and also a great series of other sediments older than the Laurentian, which have recently been proved to lie below the Huronian, and which have been named provisionally the Sudbury series.

The most recent classification of the pre-Cambrian in the Sudbury region is as follows:

Post Keweenawan (?)—Dikes of diabase and granite.

Keweenawan (?)—Nickel-bearing eruptive sheet.

Huronian—Upper Huronian (Animikie), conglomerate, tuff, slate and sandstone.
" —(Middle Huronian wanting.)
" —Lower Huronian, basal conglomerate.

Laurentian—Granite and gneiss eruptive through older rocks.

Sudbury Series—Copper Cliff arkose, McKim graywacké, and Ramsay Lake quartzite.

Keewatin—Iron Formation, greenstones and green schists.

Grenville Series—Quartzite, sillimanite schists and gneisses and crystalline limestone.

Whether the Keewatin and the Grenville series are of the same age or not is uncertain, since the two groups of rocks do not occur together.

As no fossil-bearing rocks have been found the position in time of the later eruptives is somewhat doubtful, as indicated in the table.

Interior plain of nickel basin from acid edge near Azilda.

THE GEOLOGY OF SUDBURY.

The town of Sudbury rests mainly on stratified clay underlain by quicksand formed in glacial Lake Algonquin, but hills of rock project above these lake beds, showing surfaces that have been smoothed and striated by Pleistocene glaciers. The chief rock within the town is McKim graywacké, which is well stratified with thin slaty layers the bedding showing distinctly on weathered surfaces. The beds are usually steeply tilted and are even vertical against a laccolithic mass of gabbro toward the east side of the town. The strike and dip vary considerably and in many places the greywacké is brecciated and recemented, the crushing having taken place, it is supposed, during the advent of the nickel eruptive. The graywacké is often crowded with small pseudomorphs after staurolite, suggesting contact metamorphism, which may be accounted for by the effects of the laccolithic gabbro and other eruptives in the region.

Toward the southeast on the shores and islands of Ramsay lake, the graywacké is followed by pale gray quartzite, well stratified in thick layers which are often cross bedded. They have usually a dip of about 45 deg. with a strike of northeast and southwest. The Ramsay lake quartzites form an extensive group of rocks, having a width of six miles, where widest, and an estimated thickness of 15,000 feet. They appear to overlie the graywacké, though well exposed contacts have not been found.

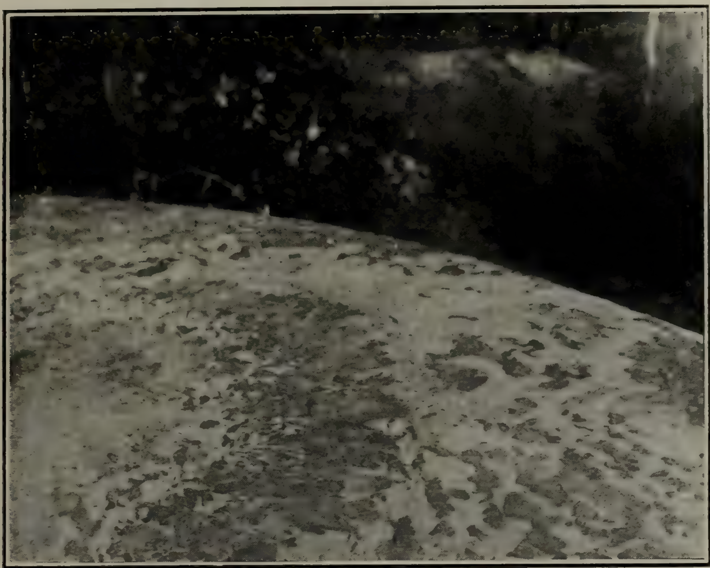
Areas of greenstone or greatly weathered gabbro penetrate the quartzite in various places, and granite or granitoid gneiss of a Laurentian type cuts them toward the south and southeast.

The quartzite, graywacké and a recrystallized arkose, rising as ridges somewhat to the west of the town, make up the Sudbury series, which is not less than 20,000 feet thick.

The most interesting of the eruptives penetrating the rocks just described forms a laccolithic range of hills in the eastern part of Sudbury, where gabbro has tipped up beds of graywacké and sometimes even overturned them slightly. The gabbro is gray-green and much weathered, consisting now mainly of hornblende and poorly preserved plagioclase; but at various points on the hills there are large patches of white rock, either "roof pendants" of quartzite partly digested, or segregations of a pegmatitic kind. These patches

Quartzite, showing cross-bedding, Ramsay Lake.

begin with a green band of hornblende on the outside, followed by an intergrowth of long blades of hornblende with white plagioclase. The latter on the inner side becomes coarse "graphic granite" with interleaved quartz, and the centre of the mass may consist of almost pure quartz. The largest example of the kind, a mile south of Copper Cliff, was worked as a quartz mine, and furnished thousands of tons of fairly pure quartz used as flux at the smelter. It seems most probable that the coarse textured rock surround-

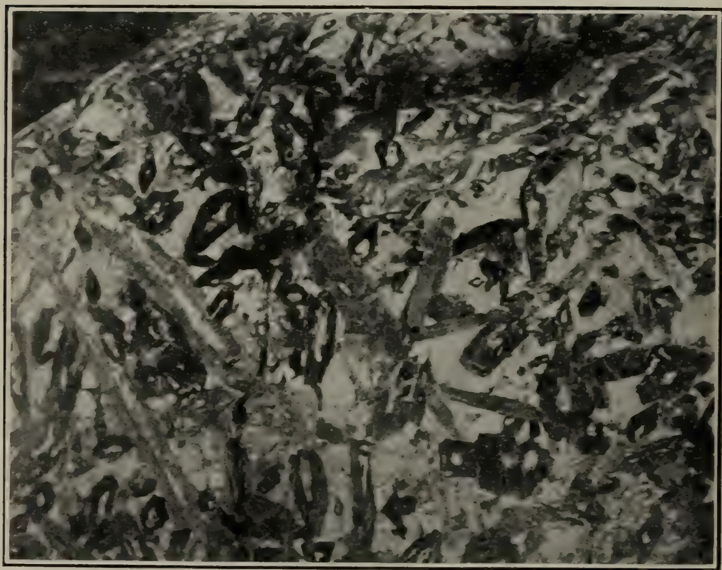


Structure in Gabbro, Sudbury.

ing the quartz is a sort of "reaction rim" about a partially digested block of quartzite. A little pyrrhotite containing some nickel occurs with these masses of quartz suggesting a relationship to the nickel-bearing eruptive a few miles to the northwest.

The sedimentary rocks of the Sudbury series mentioned above were tilted and folded and penetrated by eruptives, and then carved down to an uneven plain before the Huronian began. On the upturned edges of the quartzite a coarse

boulder conglomerate rests nearly horizontally. This has the characters of tillite, a matrix of graywacké enclosing angular, sub-angular and rounded stones of all sizes up to boulders several feet in diameter. Among these stones are many of quartzite and granite, the nearest outcrop of the latter rock occurring five miles to the southeast. No striated stones have yet been found in the tillite, perhaps because it is almost impossible to separate the stones from the matrix. Dr. Collins has traced this conglomerate northeast with



Structure in Gabbro, Sudbury.

scarcely a break to the basal conglomerate at Cobalt; and the present writer has followed it, with some intervals, to the lower Huronian conglomerate of the typical Huronian region toward the west.

The conglomerate, like the lower rocks, is often crushed into a breccia composed of large blocks cemented by more finely ground materials. This took place during the disturbances caused by the advent of the nickel eruptive. The tillite or conglomerate is the only lower Huronian rock found, and the middle Huronian is entirely absent.

INTERIOR OF THE NICKEL BASIN.

The next rock in position is the great laccolithic sheet of the nickel-bearing eruptive, which is bent into a boat-shaped syncline, 17 miles wide and 36 miles long, from southwest to northeast, with the square end of the boat at the latter end. As the sheet is really much later in age than the overlying beds, the sedimentary rocks enclosed in it will be described first. They were considered Cambrian by Dr. Robert Bell, but no fossils have been found in them, and

Onaping Falls over vitrophyre tuff.

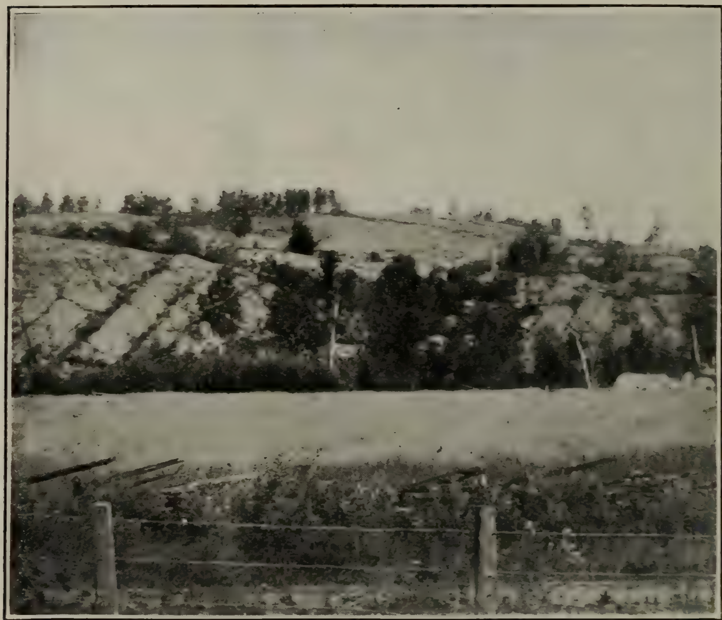
petrographically they somewhat resemble the western Animikie (Upper Huronian), so that it seems better to class them with the Upper Huronian, though their age cannot be certainly fixed at present.

There are four subdivisions exposed in very regular succession in the interior of the basin, the Trout Lake conglomerate on the outside resting directly on the upper part of the eruptive sheet, followed by the Onaping tuff, which forms an inner and wider belt; and then by the Onwatin slate; while the Chelmsford sandstone runs down the centre of the basin.

The conglomerate is coarse textured and has generally been greatly metamorphosed by the underlying eruptive

sheet so that its matrix is often changed to micropegmatite, and but for the vaguely edged boulders it would not be recognized as sedimentary. Often, too, there have been shearing motions giving a schistose structure to the conglomerate, which has even been mapped as Laurentian.

The conglomerate passes gradually into the Onaping tuff, which is well displayed at the beautiful falls of Onaping river, where there is a descent of one hundred feet over



Anticline of Chelmsford sandstone, near Chelmsford.

these rocks. The tuff is formed of sharp-angled glass fragments cemented by volcanic dust, and now transformed into chalcedony, serpentine, etc. It may be called a vitrophyre tuff, as suggested by Dr. Bonney, who first described it.

There is no distinct boundary between the tuff and the Onwatin slate, which is black and highly carbonaceous, sometimes containing ten per cent. of carbon. In it are found the curious veins of Anthraxolite (anthracitic carbon) which have aroused vain hopes of the discovery of coal. The anthraxolite, which when pure, contains 95 per cent.

Ruined anticline, Larchwood.

of carbon, as shown by Prof. Ellis, must have been fluid in the beginning, probably bitumen driven from the carbonaceous shale by the heat of the eruptive beneath. As the black slate is the softest rock in the region, it has suffered from erosion more than the rest, and is mostly covered by old lake deposits.

The Chelmsford sandstone is dark gray and might almost be called graywacké. It encloses numerous large oval concretions of impure limestone. When the Animikie beds were bent into the synclinal form the uppermost layers, especially the sandstones, were thrown into compression and rose as dome-shaped anticlinal ridges a few hundred feet high. There must have been a dozen or more of these elongated domes in the beginning, all stretching parallel to one another and to the longest axis of the basin. Now the domes are all more or less ruined, and some scarcely show above the drift deposits. One of the largest, at Chelmsford, is two miles long by a third of a mile wide, and rises about 150 feet above the plain. Several thick layers of sandstone have been removed from the top, and buttresslike remnants of beds rise from the fields on each side, so that its height must have been much greater in the beginning. A good example of a smaller anticline is crossed by the railway at Larchwood, six miles west, where the dip of the beds on each side is about 45 deg.

This sedimentary series, resting upon the nickel eruptive, has an average dip inwards of 30 deg., and has been measured up with the following results:

Upper Huronian (Animikie)	Chelmsford Sandstone ..	800 to 1,500
	Onwatin Slate	3,800
	Onaping Tuff	3,700
	Trout Lake conglomerate	20 to 400
		9,400

The black slate resembles the Animikie slate at Thunder Bay, but the remarkable tuff of glass fragments has no equivalent in the western Animikie. It appears that these relatively soft sedimentary rocks, if they ever existed in other parts of the eastern pre-Cambrian, have been completely destroyed. Their preservation here is due to the protection of the upturned edges of the nickel eruptive basin, aided by the strengthening of the Trout lake conglomerate and of the lower part of the Onaping tuff by metamorphic action due to the eruptive sheet.

Crush conglomerate in granitoid gneiss, Creighton.

THE NICKEL ERUPTIVE.

The most interesting and important feature of the region is the laccolithic sheet forming the synclinal basin and providing the great deposits of nickel and copper ore which have made the district famous. The sheet is 36 miles long and 17 miles broad with a thickness varying from half a mile to two miles and averaging a mile and a quarter. It is estimated to contain 500 cubic miles of rock, and it was once far larger, since it has lost much of its original dimensions by erosion.

The sheet consists of norite on its lower side, passing gradually into micropegmatite on the upper side. Blebs of ore are often scattered thickly through the lower part of the norite, and where there is a depression in the floor beneath this, pyrrhotite-norite merges without any break into ore bodies sometimes containing millions of tons of pyrrhotite and other sulphides. Unquestionably all three substances, ore, norite and micropegmatite, belonged originally to the great flood of molten rock which rose from some hearth beneath and spread out over the old eroded surface of ancient rocks, including the Sudbury series and the Laurentian gneisses; and under the flat-lying Animikie sediments just described. As the magma welled up from beneath, the floor of older rocks collapsed into large or small blocks which settled down allowing the sheet itself with the overlying sediments to assume the synclinal form.

Thus more than a mile's thickness of molten rock was blanketed by 9,400 feet of sediments, so that the cooling must have gone on extremely slowly, giving time for the heavier materials to settle to the bottom, and also for the upper, more acid part of the magma to metamorphose profoundly the conglomerate immediatelv over it and to silicify and harden the lower part of the Onaping tuff, as just mentioned.

The coming up and spreading out of the norite-micropegmatite sheet profoundly shattered all the adjoining rocks, and almost everywhere beneath the sheet there is a sort of breccia or conglomerate of fragments of the underlying rock sometimes cemented by norite or ore.

The freshest norite, which often occurs close to large ore bodies and may enclose portions of the ore, consists mainly of labradorite and hypersthene, with some ordinary

Face of ore, open pit, Creighton, early stage.

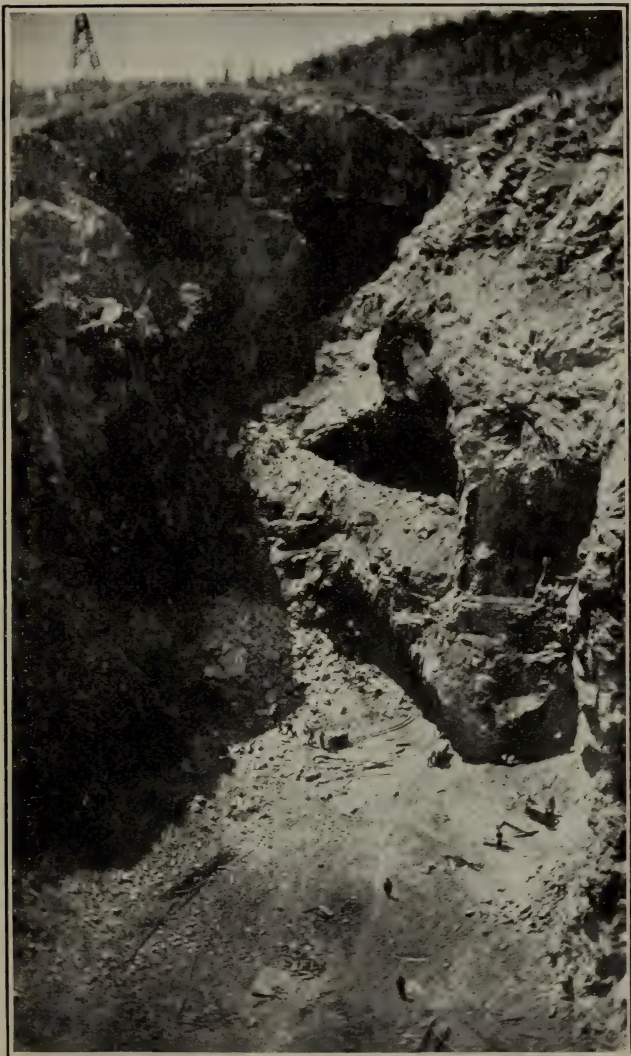
pyroxene and a few large bits of biotite. One finds also a little interstitial quartz and a few distinct blebs of bluish quartz. The most basic phase of the rock analysed contains about 50 per cent. of silica, and the most acid example of micropegmatite about 69 per cent., showing a considerable range from the bottom of the sheet to the top.

All the rocks of the district are cut by dikes of very fresh olivine diabase, some of which are 200 or 300 feet wide, and may be traced, as shown by Dr. Barlow, for seven miles, passing through norite, ore and country rocks impartially. This diabase and some dikes and irregular masses of granite are the youngest rocks of the region and may date from early Paleozoic times.

THE NICKEL DEPOSITS.

The nickel ores which give economic importance to the region are of a very uniform and monotonous character. In all the larger mines the ore consists of pyrrhotite in largest amount with subordinate quantities of pentlandite, (NiFe)S, and chalcopyrite. The pentlandite may be finely disseminated through the pyrrhotite and not apparent to the eye, but polished surfaces of the ore, as shown by Campbell and Knight, prove its presence under the microscope. The ore always contains small quantities of the norite minerals and sometimes fragments of norite or country rock. The country rock may be any of the older formations, sediments of the Sudbury series, acid or basic eruptives, or Laurentian gneiss, without in anyway affecting the ore deposit; but no ore deposit has yet been found without norite. "No norite, no ore," is the law of the district. There are, however, long stretches of the norite edge where no ore occurs, where the sheet is unusually narrow, or where the country rock bends inwards instead of outwards. There are cases where the norite edge is gossan covered continuously for more than a mile, as in the vicinity of the Murray mine.

The ore bodies may be divided into two principal kinds, marginal deposits, at low points or bays on the edge of the norite; and offset deposits, where channels lead out from such bays conveying the ore mixed with norite to various distances from the edge, sometimes even three or four miles



Creighton mine, recent condition of open pit.

The best example of a marginal deposit is at Creighton, where one of the largest bays of the norite edge has furnished the greatest nickel mine worked in the district or in the world up to the present. The Creighton mine began as an open pit, which is now nearly 300 feet deep, with lower levels worked by underground mining. The country rock is granitoid gneiss and the ore body which rests upon it dips 34 degrees inwards towards the central line of the nickel basin. The ore is unusually rich, containing about 6 per cent. of nickel and copper, the latter making up a quarter of the whole, and specimens showing pentlandite are often found. It may be distinguished from the enclosing pyrrhotite by its octahedral cleavage and brassy color as compared with the bronze of the more common mineral. The greenish yellow of the chalcopyrite is more easily recognised.

It is interesting to find that the dikes of fresh diabase cutting the rock and ore in various directions are glassy against the ore, which was a good conductor of heat, and only fine grained against norite or gneiss where the chilling was not so rapid.

The best examples of offset deposits are at Copper Cliff, where a large bay of norite narrows toward the southeast into a dike-like band of norite and ore which ends in the great columnar ore deposit of No. 2 mine. The open pit gives a good opportunity to see the shape of a characteristic offset deposit, which has been followed downwards for more than 600 feet.

A quarter of a mile to the south is the once renowned Copper Cliff mine, a still better example of this type, which reached nearly 1,300 feet in depth on an incline of 77 degrees to the east, and for years supplied the richest ore in the district, averaging nearly 9 per cent. Most offset mines are richer in copper than the marginal mines and the Copper Cliff ore contained more copper than nickel, justifying its name.

Two other deposits have been worked to the southwest and south at intervals of a quarter of a mile and of three quarters of a mile, but they were of minor importance. All of these ore bodies are associated with some norite spotted with blebs of ore, but they show no surface connections with one another or with the main mass of norite and must

Smelter, Copper Cliff.

have been supplied by devious channels between the shifting blocks of country rock. Whether these channels still exist beneath the surface or were above the present level is uncertain. Probably the present surface is thousands of feet below the original one, so that connections from above might have been eroded away.

The columnar deposits at Copper Cliff and No. 2 mine are not the most extraordinary of their kind, since two still smaller columns have been followed downwards for 1,600 feet at Victoria mine.

The Copper Cliff offset deposits occur in contact with a variety of country rocks such as granitoid gneiss and greenstone among eruptives, and graywacke and pink quartzite of the Sudbury series among sediments, without any change in the character of the ore; and they are cut by dikes of granite and diabase which have likewise had no appreciable effect in changing the original ores.

In addition to typical offset deposits where the connection with the basic edge of the nickel eruptive is manifest there is one very important band of gossan and ore which runs nearly parallel to the edge of the norite with no suggestion on the surface of any connection. This is the Frood-Stobie offset north of Sudbury, the largest known body of ore in the district. There must have been subterranean channels through which the pyrrhotite-norite and ore reached their present position in this unique case. The Frood-Stobie offset runs as a narrow gossan covered ridge with one or two interruptions for nearly two miles from southwest to northeast, and touches several types of rock, such as graywacke and greenstone, but nowhere comes within three-fourths of a mile of the norite edge.

Diamond drill cores prove that the deposit dips at first with an angle of 60 degrees or 70 degrees toward the norite, while at a greater depth the inclination flattens decidedly suggesting a broad underground connection with the parent eruptive sheet.

The Frood-Stobie offset has been proved to contain more than 35,000,000 tons of average ore and far surpasses in magnitude any other known ore body in the Sudbury region. It has already furnished half a million tons of ore and shafts are now being sunk by both the Canadian Copper Company and the Mond Company, so that it will soon add greatly to the quantity mined in the district.

THE MOOSE MOUNTAIN IRON RANGE.

At Moose Mountain about 7 miles beyond the northern side of the nickel basin and 33 miles from Sudbury by the Canadian Northern Railway, one of the largest iron ore deposits in Canada has been found. The iron formation here is separated from the northern nickel range by a band of

Banded iron formation, Sellwood.

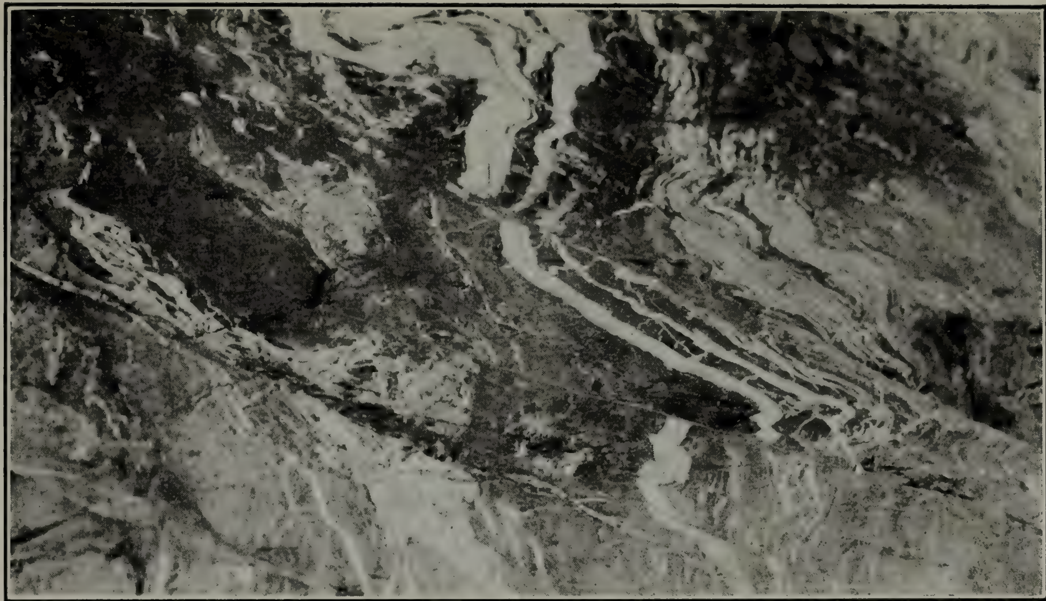
Laurentian consisting of granite, banded gneiss, greenstone and green schist, all more or less cut by pegmatite dikes. These rocks are far older than the nickel eruptive and underlie the deposits of the northern nickel range as country rock. The Sudbury series is lacking on this side of the nickel basin, so far as known, and nothing suggesting the Grenville series has been found, so that the geology to the north differs greatly from that to the south.

Moose Mountain, rising 280 feet above the plain and the railway, though one of the most important examples of the iron formation in the Keewatin of Ontario, presents less than the usual variety in the accompanying rocks, and the structural relations are more obscure than in some other regions, such as the Helen Iron Range.

In most cases the iron formation of Ontario consists of some form of silica interbanded with iron ore, either jasper with hematite or cherty or quartzitic silica with magnetite At Moose Mountain the latter material is found. Commonly the iron formation occurs as synclinal belts enclosed in green Keewatin schist; but a definite relation of this sort has not yet been proved at Moose Mountain, perhaps because the regularity has been disturbed by intrusions of greenstone and granite. The accompanying rock is a banded schist alternately light and dark gray. The iron formation here has the usual steeply tilted attitude. Often the banding is fairly straight and uniform for considerable distances, but in many cases there has been crumpling and sometimes crushing and faulting on a small scale. The ordinary banded ore contains 36 per cent. of iron, and from the results of stripping and diamond drilling, the manager of the mine, Mr. F. A. Jordan, estimates that there are 100,000,000 tons of ore of this grade. There are also 6,000,000 tons of higher grade magnetite in which there is much less silica and where the banding is less marked. Here some green hornblende is interbedded with the magnetite.

Laurentian-looking gneiss occurs just south of the iron formation but its relations to the ore bodies are not very certain; though dikes of granite and less often pegmatite cutting some of the outcrops of ore have probably come from it.

The richer parts of the ore have been greatly fissured and are penetrated in all directions by yellowish green bands or veins of epidote, evidently the last mineral formed. Beside these bands the magnetite is sometimes changed to hornblende which gradually passes into the usual ore within a few inches. The main ore body worked has been provisionally classified by Prof. Leith as belonging to the Pegmatitic type (Jour. Can. Min. Inst., Vol. XI, 1908, p. 93). He defines the type as including "ores which are



Contorted structures in iron range. Sellwood.

carried to or near the surface in magmas and are extended from them in the manner of pegmatite dikes, after the remainder of the magma has been partially cooled and crystallised. They are deposited from essentially aqueous solutions mixed in varying proportions with solutions of quartz and the silicates." He has evidently in mind the usual theory of the formation of the Kiruna and other magnetite deposits in northern Sweden. In his special reference to the Moose Mountain deposit he mentions that the ore shows " such intimate relations with greenstones as to suggest a direct derivation from them."

It should be stated, however, that some of this richer ore is interbanded with belts of the poorer silicious type making up the majority of the whole series of deposits, and it is possible that the downward percolation of hot waters may have produced the enrichment. The latest effect of circulating fluids, the formation of epidote, is generally accompanied by an enrichment of the ore near the small veins of that mineral.

Moose Mountain has been the first iron mine in Canada to concentrate its ores magnetically on a commercial scale. The higher grade ore is crushed to about inch size and separated from the intermixed epidote and hornblende by magnetic means, raising its iron contents to a merchantable grade containing 55·50 per cent. of metallic iron. The plant in use, though small and experimental, has provided 155,000 tons of ore for shipment.

This method is not effective for the 36 per cent. ore in which the magnetite is intimately mixed with silica, and within the past two years a new concentrating mill, much larger and more elaborate, has been erected. Here the ore is crushed to 100 mesh and separated magnetically by the Gröndal method. The finely divided magnetite is then compressed to drive off most of the water, briquetted and finally treated in a furnace which sinters it slightly and transforms most of the magnetite into hematite.

Though not so large as the great magnetite deposits at Kiruna and elsewhere in northern Sweden, Moose Mountain promises to become a great producer of ore. The Keewatin iron deposits of Ontario, with the exception of the Helen and Magpie Iron Mines near lake Superior, are usually similar to the one just described at Moose Mountain.

Moose Mountain Iron Mine.

There is a good deal of dispute as to their origin, though the original materials of the iron ranges are admitted by all to have been sediments of some kind.

The map of the Moose Mountain iron deposits has been prepared by Mr. E. Lindeman of the Mines Branch at Ottawa, who recently carried out a detailed magnetometric survey of the property.

ANNOTATED GUIDE.

Toronto to Sudbury via Canadian Pacific Railway.

Miles and Kilometres.

0. Altitude 254 feet. (77.4 m.) Leaving Toronto (Union Station), by way of Parkdale and West Toronto, the train passes through a manufacturing district as far as Weston. The country is heavily covered with Pleistocene deposits, consisting of boulder clays, and stratified clays, sands and gravels, which conceal the underlying Paleozoic rocks. At Weston the clay is used for the manufacture of red brick.

The surface presents on the whole a rolling appearance, and is very suitable for farming purposes. Sometimes the surface is intersected by ravines, and sugar-loaf hills have been carved from the drift, as around Woodbridge and Humber.

About 70 miles (110 km.) north of Toronto old lake deposits become abundant. Half a mile south of Carley, stratified sand showing cross-bedding is splendidly shown in a ballast pit east of the track.

96. m.
154.5 km. One mile north of Coldwater Junction the first outcroppings of rock occur. These are of banded gneiss of Laurentian age projecting as rounded knobs through the drift.

99. m.
159.3 km. North of Lovering rock exposures become more frequent, and soon a typical Laurentian area is entered.

108.5 m. North of the crossing of the Severn river
174.1 km. farming land almost disappears occurring only in small scattered areas.

This Laurentian area stretches northward continuously along this route for 150 miles (240 km.). The Laurentian consists chiefly of dark grey micaceous and reddish granitic gneisses with dikes of red granite or pegmatite.

120. m. Bala is the western gateway to the Muskoka
193. km. lakes district, famous as a resort for tourists.

132. m. Altitude 742 ft. (226. m.) Muskoka, a divis-
212.4 km. ional point, is on Lake Joseph, one of the largest of the Muskoka lakes.

155. m. At Parry Sound there is a splendid view of
249.4 km. Georgian Bay from the train as it crosses the 1,700-foot (518 m.) steel viaduct which is 120 feet (36.6 m.) above the Seguin river. (518 m.)

181. m. Another view of Georgian Bay is obtained
291.2 km. from Point au Baril.

195. m. Altitude 575 (175.3 m.). Byng Inlet is
313.7 km. located on an arm of Georgian Bay. At this point there are extensive lumbering operations.

This region of Laurentian rocks is a striking peneplain with little soil and numerous clear-water lakes and swift running streams. The marks of glaciation are everywhere seen.

255. m. Fragmental, pre-Cambrian, rocks are first
410.3 km. observed two miles south of Romford Junction. They consist of layered quartzite. At Romford the quartzite strikes east and west and dips 45 degrees S.

On the north shore of Ramsay lake, three and a half miles west of Romford, a comglomerate, which rests unconformably on the quartzite, is exposed in the railway cuttings. It out-
262. m. crops along the lake and railway to the town of
421.5 km. Sudbury.

ITINERARY AT SUDBURY.

First Day.

8 a.m.—Sudbury to Ramsay Lake.

Sudbury, alt. 855 ft., (260.6 m.), chief town of the nickel region with a population of about 5,000, is situated on a flat plain of silt deposited in a bay of lake Algonquin. Above it rise hills of the Sudbury series of rocks.

A walk of two hours' duration will be taken through the town to Ramsay lake, crossing well stratified and steeply tilted greywacké (McKim greywacké), partly brecciated during the advent of the nickel eruptive. On the shore of the lake and on islands pale grey quartzite dips at an angle of 45 degrees southwest. It extends in that direction six miles (9.6 km.) and is estimated to have a thickness of 15,000 feet (4,500 m.). North of Ramsay lake the Basal Huronian tillite is seen resting unconformably on the quartzite. It contains pebbles and boulders of quartzite, greywacké and granite.

Northwest of the conglomerate a hill of laccolithic gabbro will be visited, halting first at a dike of fresh olivine diabase. Climbing the hill there are good views of the town and of Ramsay lake. On top of the hill one may study certain curious "roof pendants" (or acid segregations) having quartz in the centre, followed by pegmatite and by coarse-grained hornblende-albite rock, with a rim of hornblende in large bladed crystals.

From the laccolithic hill the party will return through the town to the special train. The total distance walked is two miles (3.2 km.).

10. a.m.—Sudbury to Levak.

Leave Sudbury by special train on the main line of the C.P.R. going northwest for 1½ miles (2.4 km.) through McKim greywacké, followed by pink arkose, (Copper Cliff arkose), following for some distance a great dike of diabase which may be seen in cuttings. After a steady ascent of four miles (6.4 km.), the latter part through greenstone and granite, the summit is reached at Murray mine, alt. 992 feet, (302.3 m.), where the railway crosses the gossan-covered edge of the nickel-bearing norite. Murray mine is one of the oldest of the nickel mines in the district but has not been regularly worked for many years.

The railway runs for two miles (3.2 km.) through a nearly flat plain formed of the dark grey, easily weathered norite, cut in one or two places by later granite. The norite then merges into reddish grey micropegmatite rising as rugged hills.

At Azilda, alt. 891 (271.8 m.), 7 miles (11.3 km.) from Sudbury, the railway enters the interior plain of the nickel basin, having come in by the easiest pass through the acid edge of the nickel eruptive. This plain of farmlands is formed of silt deposited in a bay of lake Algonquin, and Whitewater lake, a mile to the south, lies at the boundary of the interior sedimentary rocks against the eruptives. All round the basin, which is 35 miles (56.3 km.) long and 10 (16.1 km.) wide, may be seen hills of micropegmatite and of conglomerate which it has metamorphosed.

At Chelmsford, alt. 888 feet (270.6 m.), 12 miles (19.3 km.) northwest of Sudbury, in the middle of the basin, low anticlinal domes of sandstone begin, one of the largest lying southeast of the village.

At Larchwood, alt. 885 feet (269.7 m.), 18 miles (29 km.) from Sudbury the railway cuts through one end of a ruined dome just east of the Vermilion river, which crosses the upturned edges of sandstone as pretty rapids.

At Phelans, alt. 937 (285.6 m.), 21 miles (33.8 km.) from Sudbury, the railway ascends a gravel terrace, a delta deposit of the river where it entered lake Algonquin. and not far beyond is the beautiful falls of Onaping river, more than 100 feet (30.4 m.) in total height, over Onaping tuff, the third member of the Animikie as found in the nickel basin.

At Levak siding, alt. 1,020 feet (310.9 m.), 24 miles (38.6 km.) from Sudbury, the railway is in the midst of high and rugged hills of micropegmatite.

Three miles beyond, near Windy lake, alt. 1,221 feet, (373.7 m.), the basic edge of the nickel eruptive is found. A few hundred yards of drift, including an esker ridge, separate the last outcrop of norite from the Laurentian, which rises as the usual hummocky hills of gneiss.

After traversing the whole width of the nickel basin by train it is intended to halt for a study of various points of interest on the way back. A walk lasting two hours and covering about 3 miles will be made along the railway east-

wards from Windy lake, giving an opportunity to examine Laurentian granitoid gneiss near Windy lake and outcrops of fresh norite to the east. Unfortunately the contact of the norite with the gneiss is hidden by fluvio-glacial deposits.

Continuing eastwards the gray norite passes into a reddish, syenitic-looking intermediate rock, and the valley narrows between precipitous hills at Levak siding, where the train will await the party and lunch will be taken.

After lunch the walk will continue for two miles to Onaping falls and Phelan. The micropegmatite phase (acid edge) of the nickel eruptive occurs as a rather pale gray rock when Onaping river is reached. Next is seen the basal conglomerate of the Animikie much metamorphosed by the underlying eruptive sheet; and this passes at the beautiful Onaping falls into vitrophyre tuff crowded with small glass fragments now turned to chalcedony or serpentine. The walk of about 2 miles ends at Phelan where there are good sections of the delta gravels formed by Onaping river in a bay of ancient lake Algonquin. Here the train will be taken to Larchwood.

At Larchwood a short walk will be made to a good example of the anticlinal hills of the interior basin. Vermilion river and the railway make their way across the ruined southeastern end of the anticline.

The train will then be taken to Murray, where a walk of about 2 miles will show the gossan covered basic edge of the norite resting on a complex of ancient lavas showing, in places, amygdaloidal and pillow structures. The lava when fresh has the composition of a norite, but is earlier than the nickel-bearing norite and more basic in character. Following a suggestion of Dr. Miller it is proposed to call this effusive variety of norite Sudburyite. Its relation to norite is similar to that of basalt to gabbro.

A hill of this rock just south of the old Elsie nickel mine affords a good view of the nickel range and the interior basin.

At Murray diamond drills will be seen at work determining the attitude and thickness of the nickel ore body, which is already known to reach a depth of 1,100 feet and to include more than 10,000,000 tons.

Return to Sudbury in the evening.

Second Day.

7 a.m.—Leave Sudbury by Algoma Eastern railway for Creighton, passing for 2 miles (3.2 km.) through greywacké, followed for a mile (1.6 km.) by arkose and then by greenstone. At 3½ miles (5.6 km.) west a branch runs south to Copper Cliff. Beyond this greenstone and granite extend to the norite of the Copper Cliff offset, here about a mile (1.6 km.) wide. For the rest of the journey the railway runs southwest near the contact of the norite with coarse granitoid gneiss.

Creighton, alt. 973 feet (296.5 m.) is 11 miles (17.7 km.) by rail west of Sudbury. The party will walk south through the village to a hilltop of granite and gneiss from which there is a broad outlook over the gossan edge of the nickel range and the mine with its surroundings. The hill displays interesting crush conglomerates as well as small faults caused by the arrival of the nickel eruptive. A walk will then be made past the east end of the mine to a characteristic contact of norite with the older gneiss; after which the gossan hill and the great open pit, 300 feet (91.4 m.) deep, will be visited. Those who wish may descend 60 feet (18.3 m.) to the first level of the mine, following the foot wall of the ore body.

Specimens of pyrrhotite, chalcopyrite and probably pentlandite may be obtained, as well as of pyrrhotite-norite, ordinary norite, and diabase, the latter cutting the ore.

10 a.m.—Return by the A.C.R. to Clarabelle junction, where the Canadian Copper Company's line will be taken south for 2 miles (3.2 km.) to Copper Cliff.

The line passes through the great roastyard where heaps of ore from the Creighton and other mines may be seen at every stage, some in process of building, others steaming with sulphur fumes, and others forming rusty heaps of well roasted ore.

Beyond this is the rockhouse of No. 2 mine, and then the large buildings and stacks of the smelter, followed by the town of Copper Cliff with its polyglot population of 2,500, mainly from Finland and southeastern Europe.

A walk will be taken to Lady Macdonald lake, where the edge of the norite narrows to a funnel leading to

the long and important Copper Cliff offset, passing through granitoid gneiss, greenstone and greywacké.

No. 2 mine, with its open pit 300 feet (91.4 m.) deep, in a typical columnar offset deposit.

The Copper Cliff mine itself is not now working but will be visited as the richest and one of the most important of the early mines. The ore body formed an irregular chimney which has been followed for 1,300 feet (400 m.) on an incline of 70 degrees to the east.

After visiting Copper Cliff the party will be taken to the smelter, 2-3 of a mile (1.1 km.) northeast, where officers of the Canadian Copper Company will guide them through the various buildings and explain the processes. The plant is one of the largest and most complete in North America.

The destruction of all vegetation in earlier years by roast beds near the town has allowed rain erosion of a striking kind on the old lake deposits in and near Copper Cliff.

During the afternoon the party will return to Clarabelle junction and travel 4 miles (6.4 km.) northeast on the Canadian Copper Company's private railway to Frood or No. 3 mine, passing most of the way through greenstones.

At Frood the gossan-covered ridge will be ascended to give an idea of the largest known nickel deposit in the world, estimated to contain more than 35,000,000 tons of ore, perhaps even 100,000,000 tons. It extends almost unbroken for a mile to the southwest and almost as far to the northeast, where the Stobie mine once produced more than 400,000 tons of ore. After testing it with the diamond drill the Canadian Copper Company has sunk two shafts and begun work on the deposit, and the Mond Nickel Company, which owns the Frood Extension, taking in a part of the centre of the ridge, is sinking a third shaft.

The Frood-Stobie offset, unlike all others, shows no surface connection with the main nickel range, from which it is separated by about a mile (1.6 km.) of granite hills. The deposit may be described as a parallel offset. It doubtless has underground channels connecting it with the norite to the northwest, since drill holes show that the ore body dips that way.

Evening.—Return to Sudbury, where a complimentary banquet will be given by the Board of Trade for excursion A 3.

Third Day.

Leave Sudbury early in the morning by a branch of the Canadian Northern railway running 5 miles (8 km.) north and east to Sudbury junction, crossing a plain of old lake deposits (Algonquin) and rounding the hill of laccolithic gabbro in the eastern part of Sudbury. Near Sudbury junction quartzite may be seen to the south and east.

At Sudbury junction the Sudbury branch joins the main line 261.7 miles (421.1 km.) north of Toronto.

From the junction the line runs northwest through quartzite for two miles, followed by greywacké and greenstone, until the basic edge of the nickel eruptive is reached. Here the line turns north, passing Garson lake, which is in the micropegmatite phase of the eruptive. The whole width of the eruptive at this point is 2½ miles (4 m.), and the norite and micropegmatite are like those seen at Levak.

Passing the hilly acid edge of the eruptive and the Trout lake conglomerate, the flat interior plain of sand and silt deposited in a bay of lake Algonquin is entered. To the south, east and north can be seen the rugged inner rim of the nickel eruptive.

At Hanmer, 271.8 miles (347.4 km.) north of Toronto, a hill of Onaping tuff rises to the east, and a mile or two north black slate is seen near Onwatin lake.

The railway now follows the valley of the Vermilion river. To the west there is a high terrace of fluvio-glacial gravel, and at mile 273 the beach gravels of lake Algonquin are used for railway ballast.

Near mile 278 tuff may be seen passing into conglomerate at the northern side of the basin, and just beyond there are the usual hills of the "acid edge." The basic or norite edge of the nickel eruptive occurs at Nickelton junction, where the Nickel Range railway runs 4 miles (6.4 km.) east to Whistle mine.

To the north of the junction the railway enters the Laurentian, crossing coarse red granite and granitoid gneiss, with bands or larger areas of green schist or greenstone as far as Sellwood junction at mile 284.3.

From Sellwood junction a branch runs 5 miles (8 km.) northwest to Sellwood, where the Moose Mountain iron mines will be visited.

9 a.m.—No. 1 mine, near the brow of the hill, is worked largely as an open pit where magnetite more or less interbanded with hornblende and green epidote occurs, and a fault plane forms a slickensided wall on the west side. Granite occurs as dikes in greenstone and green schist near the ore, but does not actually touch it.

In a large stripping a quarter of a mile west granite dikes are seen penetrating the ore or running parallel to its banding.

A walk of a mile, mostly over drift deposits but passing some banded Keewatin schist, leads to the iron dam, or No. 2 mine, where the ore is very different, consisting of interbanded silica and magnetite without hornblende or epidote. This ore is leaner, containing only 36 per cent. of iron. Where the iron formation crosses the Vermilion river interesting crumplings and foldings of the banded ore may be seen.

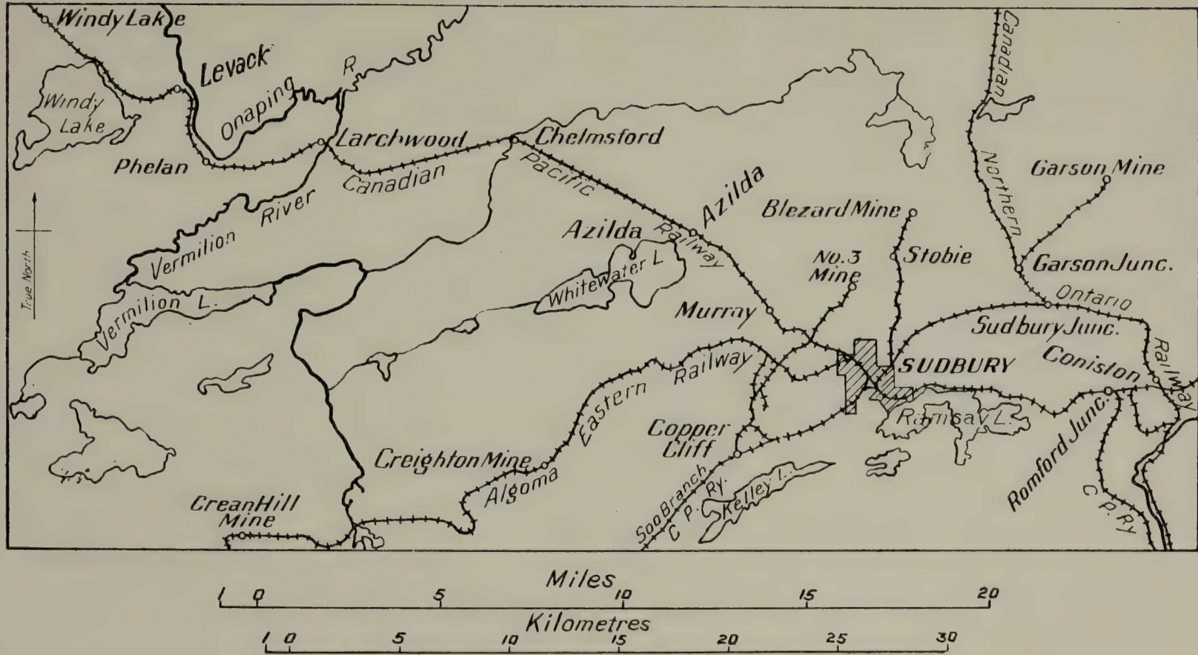
Half a mile farther north, near the new concentrator, a stripping shows banded ore cut by dikes of granite and by thin seams of epidote. A variety of interesting small scale structural features can be seen here, such as anticlines and synclines and faults of different dimensions.

Officers of the Moose Mountain iron mine will take the party through the mill and explain the methods of magnetic separation and briquetting, by which the 36 per cent. ore furnishes a high-grade product. Those who wish may visit a saw mill at work near the village.

Afternoon.—Leave for Sudbury. If time permits a stop may be made at mile 278 to observe a good contact of the micropegmatite with the Trout lake conglomerate.

Towards evening the smelter of the Mond Nickel Company at Coniston will be visited, giving an opportunity to see the latest and one of the most complete smelting plants in Canada.

Arrive at Sudbury in the evening.



Sudbury Nickel Area.

THE COBALT AREA

BY

WILLET G. MILLER.

CONTENTS.

INTRODUCTION.

In 1903, during the construction of the Temiskaming and Northern Ontario Railway, which is owned and operated by the Ontario Government, rich veins of cobalt-silver ore were discovered near what is now known as Cobalt station. The railway track runs almost over the top of one of the most important veins yet found.

At the time the discovery was made, the veins attracted little attention, the discoverers not being men whose vocation was that of prospecting or mining.

Niccolite is a characteristic mineral of the area, and, as its German name, kupfer-nickel, indicates, its color is somewhat like that of copper. Hence, it is not surprising that some of the first persons to see the deposits mistook the niccolite for copper ore, and, not having their attention drawn to the native silver, which occurred in profusion in parts of the veins, should have decided that the deposits were of the less precious metal. A sample of the niccolite, received at the Bureau of Mines toward the end of October of the year mentioned, aroused the writer's interest and he decided to visit the locality from which it came.

The great Sudbury nickel area lies 90 miles to the southwest of Cobalt, and in a report on a trip of exploration to the vicinity of what is now Cobalt, in 1901, the writer had said:

" It will be seen from what has been stated on preceding pages that the district examined contains as great a variety of rocks as probably any other part of the Province of equal area. . . .

" Although few discoveries of economic minerals have been made in this territory, it may reasonably be expected, judging from the character and the variety of the rocks, that deposits of value will be found when the district is more carefully prospected, as it will be in a short time, owing to the rapid settlement which is now taking place. . . . It would seem that at least some of the conditions of the Sudbury district are repeated in this more eastern field."*

*11th Report, Ontario Bureau of Mines, p. 229.

Cobalt station, June, 1905.

Naturally, on the receipt of the sample of niccolite, it appeared that this prediction might have been verified, and that deposits of nickel vastly richer than those of Sudbury might have been discovered.

On examining the veins then discovered, four in number, all near the shore of Cobalt lake, an unexpected and astonishing assemblage of minerals was seen, the most prominent being native silver, niccolite, smaltite and cobalt bloom. In the first paper he published on the area, describing one of the veins, the writer said:

"Here a perpendicular bare cliff, 60 or 70 feet high, faces west. The vein. . . . cuts this face at right angles, having an almost vertical dip. . . . When I saw it first it had not been disturbed. Thin leaves of silver up to two inches in diameter were lying on the ledges and the decomposed vein matter was cemented together by the metal, like fungus in rotten wood. It was a vein such as one reads of in text-books, but which is rarely seen, being so clearly defined and so rich in contents."*

The veins are narrow, averaging not more than 4 inches (10 cm.) in width. This feature discouraged certain of the first mining engineers who examined the outcrops, and caused them to doubt whether the veins were of economic importance. However, the large number of veins and their great richness has more than compensated for their narrowness.

It was soon proved by comparatively little work that Cobalt was really a "poor man's camp." One of the first operators, for instance, extracted ore having a value of approximately $250,000 at a total cost of $2,500. Statistics show that during the period of mining in the area dividends distributed have been equal to over fifty per cent. of the value of the output.

In the earlier years of mining there were no refining plants, in North America at least, that could economically treat the ores. Owing to the unusual and complex character of the ores there was waste of other constituents in extracting silver, there being present in addition to the precious metal, arsenic, cobalt and nickel in important quantities.

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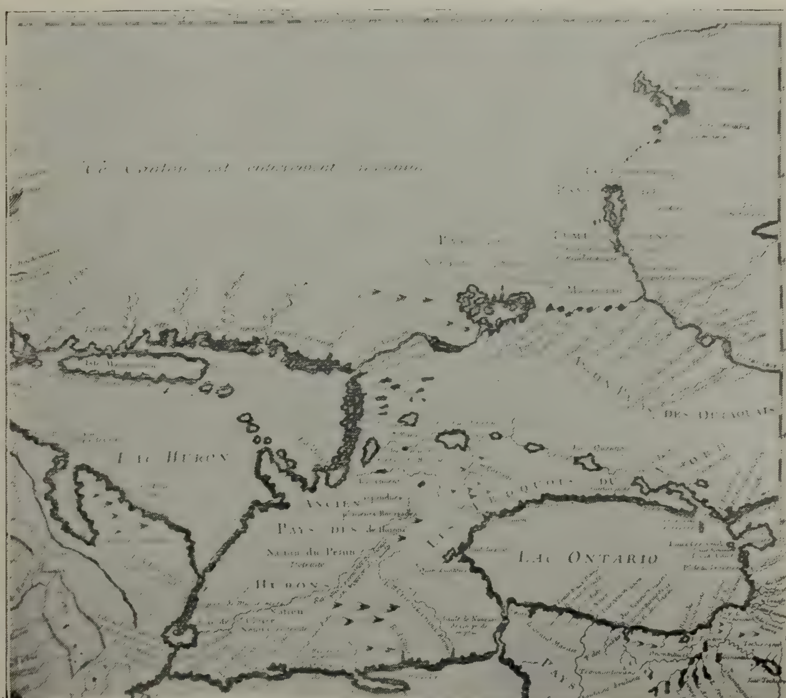
*Eng. and Min. Jr., Dec. 10th, 1903.

The Cobalt area is not unique in Ontario in possessing an unusual ore, other representative economic minerals of the Province when discovered being without a market or requiring the development of a refining process. The Sudbury deposits, for example, were opened up for copper, nickel being afterwards found to be present. A considerable period elapsed before refineries were developed and a



Part of a map published in 1744, showing that the argentiferous galena deposit on the east side of lake Temiskaming (Ance à la mine), about nine miles from Cobalt, was known at that date.

market made for the nickel by proving to the nations of the world its value as a constituent of steel for armour plate. Again, in the earlier years of apatite mining in Ontario, the amber mica, which is now so highly prized, associated with this mineral, was thrown on the waste heaps. And when the corundum deposits were discovered, a process

had to be developed for milling the rock and a market had to be made for the material. Other instances could be cited, but the examples given show that the characteristic of the minerals mined in Ontario's pre-Cambrian rocks is uniqueness.

It is gratifying to know that within the comparatively few years that mining has been prosecuted at Cobalt, plants capable of refining all of the constituents of the ore have been erected in Ontario, the processes employed being either improvements on those in use elsewhere or invented especially for these ores, such as that employed at the Nipissing mine for the extraction and refining of silver. This metal is refined at several other plants, and white arsenic and cobalt and nickel oxides are produced. The plants for refining cobalt oxide in Ontario are of capacity sufficient to supply the world's demand for the material. The white arsenic produced from Cobalt ores represents about 20 per cent of the world's output. Cobalt is the world's greatest producer of silver, its output representing about 13 per cent of the whole.

In 1904, the year in which the first shipments were made, there were produced 158 tons of ore. The average percentages of the four metals in this ore were:

Silver	5.34	per cent., or 1,309.33 ounces per ton.
Cobalt	10.21	" "
Nickel	8.86	" "
Arsenic	45.56	" "

In 1905 there were shipped 2,144 tons of ore of the following composition:

Silver	3.90	per cent., or 1,138.72 ounces per ton.
Cobalt	5.50	" "
Nickel	3.49	" "
Arsenic	25.60	" "

The ore shipped till near the end of 1907 was sorted by hand, or with crude mechanical appliances. Since then extensive concentrating plants have been erected.

Production of Cobalt Mines, 1904-1912

The following table summarizes the production of the Cobalt and adjacent areas.

Year.	Ore shipped	Nickel		Cobalt		Arsenic		Silver		Total value
	Tons	Tons	Value	Tons	Value	Tons	Value	Ounces	Value	
			$		$		$		$	$
1904.............	158	14	3,467	16	19,960	72	903	206,875	111,887	136,217
1905.............	2,144	75	10,000	118	100,000	549	2,693	2,451,356	1,360,503	1,473,196
1906.............	5,335	160	....	321	80,704	1,440	15,858	5,401,766	3,667,551	3,764,113
1907.............	14,788	370	1,174	739	104,426	2,958	40,104	10,023,311	6,155,391	6,301.095
1908.............	25,624	612	....	1,224	111,118	3,672	40,373	19,437,875	9,133,378	9,284,869
1909.............	30,677	766	....	1,533	94,965	4,294	61,039	25,897,825	12,461,576	12,617,580
1910.............	34,282	504	....	1,098	54,699	4,897	70,709	30,645,181	15,478,047	15,603.455
1911.............	26,653	392	....	852	170,890	3,806	74,609	31,507,791	15,953,847	16,199.346
1912.............	21,933*	....	....	515	317,165**	1,96¼***	79.297	30.243,859	17,408.935	17,805,397
Total........	....	....	....	....	....	....	....	155,815,839	81,731,115	83,184,268

*Does not include ore refined at Cobalt. **Cobalt oxide, etc. ***Refined.

For some time after mining began at Cobalt, the ore was shipped to the sampling works of Ledoux and Company, New York. The richest shipment contained 7,402 ounces of silver to the ton, the next in order being 6,909; 6,413; 6,163 and 5,948 ounces to the ton. The average percentages of other metals in the 366 carload lots sampled by this firm were: cobalt, 5.99; nickel, 3.66; arsenic, 27.12.

Concerning the high-grade ore at Cobalt, Mr. R. B. Watson recently has said: "A typical ore carries 10 per cent. silver, 9 per cent. cobalt, 6 per cent. nickel, and 39 per cent. arsenic; the rest is lime, silica and smaller amounts of antimony, iron, sulphur, tellurium, etc."*

The most productive vein in the area is that known as the Carson, on the Crown Reserve property. It has been estimated that this vein, with its extension on the Kerr Lake property, will have produced before being exhausted 20,000,000 ounces or more of silver from that part of it above the 200-foot level.

The richness of the ore in various mines is well shown by what it has cost, on the average, to produce an ounce of silver. In 1911, for example, the cost per ounce, including mining and all other expenses, given in the annual reports of certain companies, was: at the Crown Reserve, 10.761 cents per ounce; at the Coniagas, 8.8; at the Nipissing, 13.95; and at the Kerr Lake, 14.69.

The chief object in building the Temiskaming and Northern Ontario railway was the development of the agricultural areas at the head of Lake Temiskaming, to the north of Cobalt. It was also felt that the railway would increase the value of the timber lands through which it passed, but, it is safe to say, the most sanguine supporters of the policy of railway building little dreamed of the mining development to which the construction of the road would lead. It is true that mining at Sudbury had been pursued for some years before it was decided to build the railway into the Temiskaming country, but Sudbury had never excited much interest among the people of Ontario. Those who were inclined to invest in mines had little faith in the mineral resources of their own Province. The discovery of Cobalt, however, has given confidence in the Pro-

*Eng. and Min. Jr., Dec. 7th, 1912

vince's mineral industry and has led to the development of Porcupine and other areas tributary to the railway. The value of the ore produced at Cobalt, in less than ten years, is equal to about five times the cost of constructing and equipping the 252 miles of railway from North Bay to Cochrane, together with branch lines, and the dividends alone are equal to two and a half times the total cost of the railway.

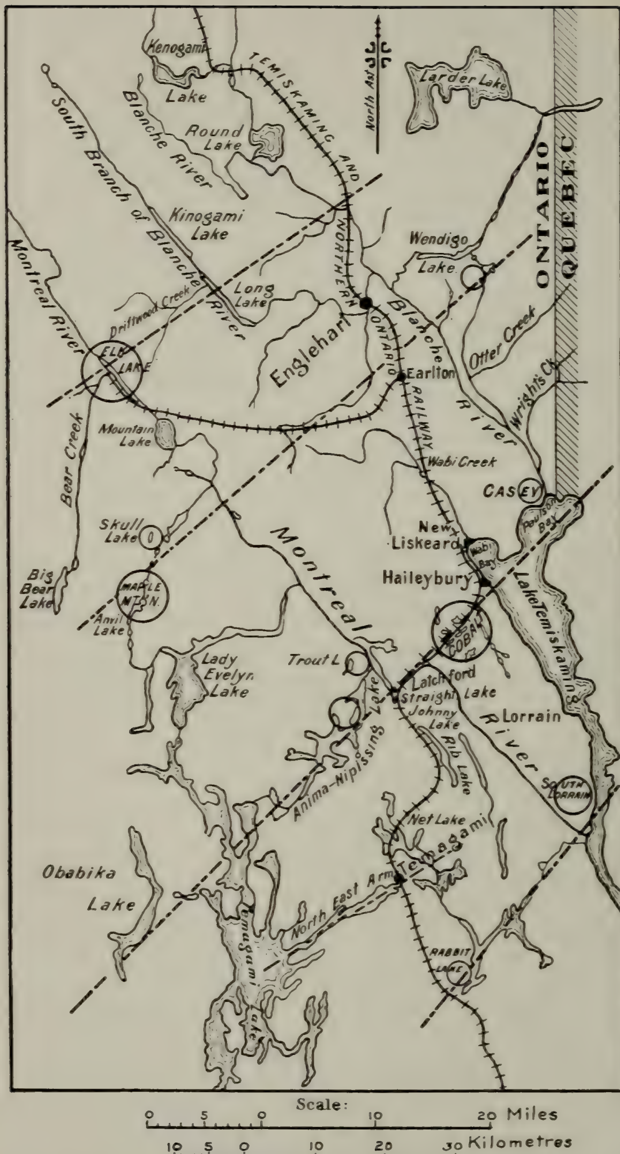
Moreover, the discovery of Cobalt, which lies near the southern edge of the great pre-Cambrian regions that occupy nearly one-half the surface of Canada's 3,750,000 square miles of territory, has given confidence in these regions as storehouses of economic minerals and ores that future prospecting will bring to light.

THE ROCKS AND THEIR RELATIONSHIPS.

At first, owing to the surface being covered with green timber and to the presence of much drift material, contacts and good exposures were difficult to find. Now, that the timber has been removed parts of the area have almost the appearance of a large model, e.g. between the northwestern face of Mount Diabase and Peterson and Cart lakes, or on the Nipissing property to the west of Peterson lake, where the loose deposits have been removed from the surface by hydraulicing.

From the maps of the area that have been published, it will be seen that there is considerable variety in the pre-Cambrian series. On the shores and islands of Lake Temiskaming, a few miles to the north or northeast of Cobalt station, the Clinton and Niagara of the Silurian system also show prominent outcrops. Between the Niagara and the Pleistocene or Glacial there are no formations represented in the district.

The following table shows the subdivisions, based on age relations, that have been made among the rocks of the Cobalt area proper. Representatives of most of these subdivisions of the pre-Cambrian are found in other areas that have been carefully mapped in the surrounding region.



N.W.-S.E. and N.E.-S.W. lines of regional disturbance in the district of Temiskaming and the cobalt-silver areas.

In the Porcupine gold area, one hundred miles to the northwest of Cobalt, the Keewatin and Temiskaming series are prominent. The Cobalt series is also present in this area, and certain dikes are believed to represent the Nipissing diabase of Cobalt.

In the Gowganda silver-cobalt area, which lies fifty or sixty miles to the west of Cobalt, the Nipissing diabase and Cobalt series occupy much of the surface. The Temiskaming series is found in good exposures in part of the area. The latter series has also been found at Swastika and Larder lake, at Abitibi lake, 75 miles north of Cobalt, and eastward across the boundary in Quebec. It is thus known to occur at various points over a large region.

It is possible that unconformities that have not been discovered exist in the pre-Cambrian of the Cobalt and adjacent areas. Moreover, the relationship which the Cobalt and Temiskaming series have to the fragmental rocks of the classic Huronian area of the north shore of Lake Huron is not known. Hence, in the following table the name Huronian is not employed. If the Huronian is considered to include all the post-Laurentian and pre-Keweenawan fragmental rocks of the region, then both the Cobalt and Temiskaming series come under this heading.

The dual subdivision of the pre-Cambrian into Algonkian and Archean, or Proterozoic and Archeozoic, employed by many authors, is not adopted by the writer, since he believes that the Grenville series, which includes limestones and other sediments of great thickness, is of pre-Laurentian age. Thus a dual subdivision of pre-Cambrian rocks, based on arguments that have been employed in its behalf, fails. If a name is desired for the pre-Cambrian rocks, to correspond with Paleozoic and Mesozoic, the well-known name Eozoic may be used.

Age Relations of Rocks of Cobalt and Adjacent Areas.

PALEOZOIC	
SILURIAN **Niagara**	Prominent outcrops of Niagara limestone, with basal conglomerate and sandstone, occur on some of the islands and the shores of the north end of lake Temiskaming.
(*Great unconformity.*)	
EOZOIC OR PRE-CAMBRIAN	
LATER DIKES	Aplite, diabase, basalt.
NIPISSING DIABASE (*Intrusive contact.*)	This diabase, which is of such great interest in connection with the cobalt-silver veins, is believed to be of Keweenawan age. Certain aplite dikes are genetically connected with the diabase.
COBALT SERIES (*Unconformity.*)	The Cobalt series includes conglomerate, greywacké and other fragmental rocks.
LORRAIN GRANITE (*Intrusive contact.*)	This granite occupies a considerable part of the township of Lorrain and has large exposures elsewhere in the vicinity of lake Temiskaming.
LAMPROPHYRE DIKES (*Intrusive contact.*)	Lamprophyre dikes are to be seen near some of the mines at Cobalt.
TEMISKAMING SERIES (*Unconformity.*)	Like the Cobalt series, the Temiskaming consists of conglomerate and other fragmental rocks.
KEEWATIN COMPLEX	The Laurentian, gneiss and granite, which in age lies between the Keewatin and Temiskaming, is absent in the Cobalt area proper, but is found in the surrounding region. Under the heading Keewatin are grouped the most ancient rocks of the region. They consist essentially of basic volcanic types, now represented by schists and greenstones, together with more acidic types, such as quartz-porphyry. With the Keewatin are included certain sed ments, such as iron formation or jaspilyte, dark slates and greywackés, which probably represent the Grenville series of southeastern Ontario. Certain dike rocks that are grouped with the Keewatin may be of post-Temiskaming age, but since they have not been found in contact with the Temiskaming series their age relationships are unknown.

NOTES ON THE ROCKS.

KEEWATIN

The Keewatin rocks, of the Cobalt area proper, fall into four groups: (1) Basalts, (2) Diabases and other basic rocks, (3) Acid intrusives, (4) Sediments. Of these the basalts are the most common. The diabases are also of common occurrence, although they are not so

Torsion cracks in Keewatin greenstone, Cobalt.

widely distributed as the basalts. The acid intrusives are of infrequent occurrence in the Cobalt area. They include felsite, feldspar-porphyry and quartz-porphyry. The sediments grouped with the Keewatin include iron formation (jaspilyte, chert and greywacké), graphite schists and slates.

Many of the basic, igneous rocks of the Keewatin have been rendered schistose and their original character cannot now be definitely determined.

The acid intrusives of the Keewatin are on the whole younger than those of more basic composition. Certain diabases are intrusive into the basalts and iron formation.

No granite, or granite gneiss, older than the Lorrain granite, occurs in the immediate vicinity of Cobalt, but certain pebbles and boulders in the conglomerates of the silver area have been derived from the Laurentian.

The name Laurentian is applied to granite or granite gneiss, typically of grey color, the gneiss frequently possessing alternate dark and light colored bands. The well-banded gneiss owes its composition and structure to the inclusion of fragments and masses of Keewatin in the intrusive granite, which have been squeezed or drawn out.

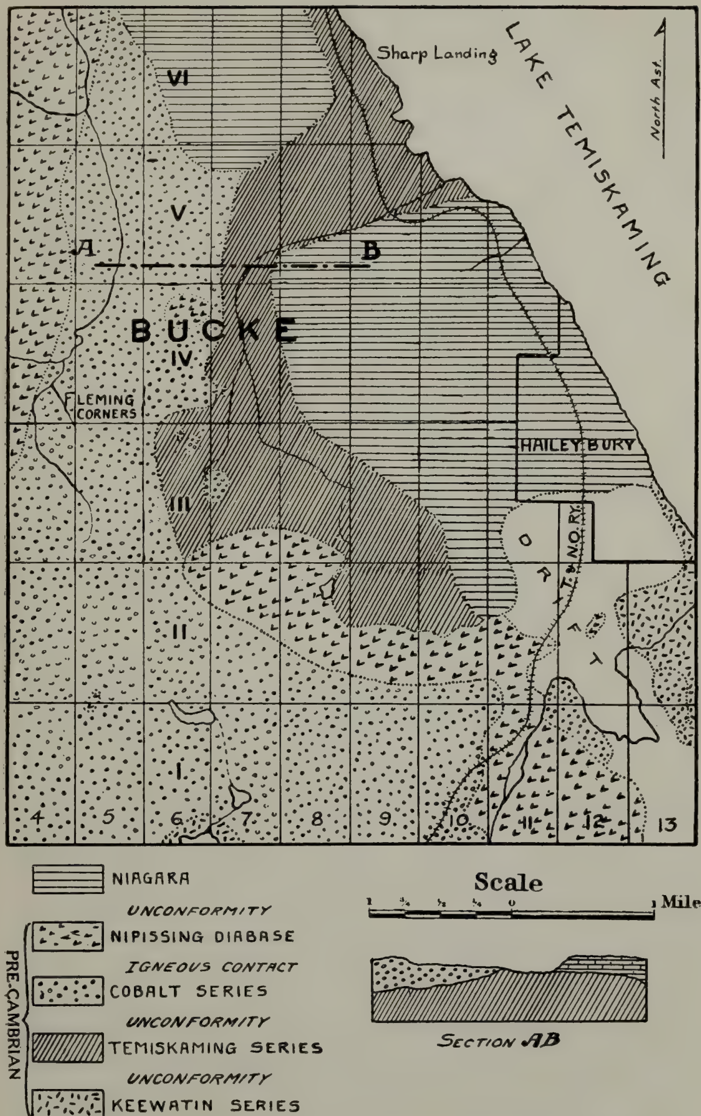
The Laurentian intrudes both the Keewatin and the Grenville series. The Temiskaming is the oldest fragmental series known in the region that is of post-Laurentian age.

THE TEMISKAMING SERIES

The Temiskaming series is composed of conglomerates, greywackés and slates. The conglomerates show a great variety of pebbles, including the following: basalt, diabase, green schist, pyroxene or hornblende-porphyry, quartz-porphyry, feldspar-porphyry, felsite, jaspilyte, grey, white and red cherts, grey granite, granite gneiss and coarse porphyritic syenite with crystals of feldspar one-half to one inch in length.

The Temiskaming series is generally distinctly bedded, and the strata are everywhere seen to have been tilted up until they now rest in a vertical, or almost vertical, attitude. Cross-bedding has been noted in some of the greywackés. Along the shores of lake Temiskaming, between Haileybury and New Liskeard, the strike is easterly, observations giving strikes of N. 60 degrees to 70 degrees E., and steep dips to the south. At the northwest corner of lot 8, in the second concession of Bucke, the strike is N. 20 degrees W., with steep dips to the east. In various places the series is intersected by quartz stringers a few inches in width and a foot or more in length.

An unconformity is inferred to exist between the Laurentian granites and gneisses and the Temiskaming sediments, because granite, syenite and granite gneiss pebbles are found in these sediments.



Geological map of area a few miles north of Cobalt.

The Temiskaming series was invaded, first by lamprophyre dikes, and later by the great mass of Lorrain granite. Good contacts of the Lorrian granite and Temiskaming series are to be seen immediately south of the Temiskaming mine, and at Kirk lake.

West of Haileybury about three miles, an unconformity is exposed between the Temiskaming and Cobalt series. Here, at the southwest corner of lot 7, in the fourth concession of Bucke, the Cobalt conglomerate rests on the upturned edges of the Temiskaming greywacké, the latter showing distinct bedding. Nearby, the older series is cut by lamprophyre dikes, which do not, however, invade the Cobalt sediments. In the same neighborhood there are several places where the two series are separated only by a few feet of drift, but the discordance of the dips is so striking that there can be little doubt about the existence of the unconformity. At Fleming Corners the flat lying, slate-like greywackés of the Cobalt series are in marked contrast to the disturbed Temiskaming sediments one-half mile to the east.

Boulders of conglomerate of the Temiskaming series are found in the conglomerate of the Cobalt series, as shown in the accompanying illustration.

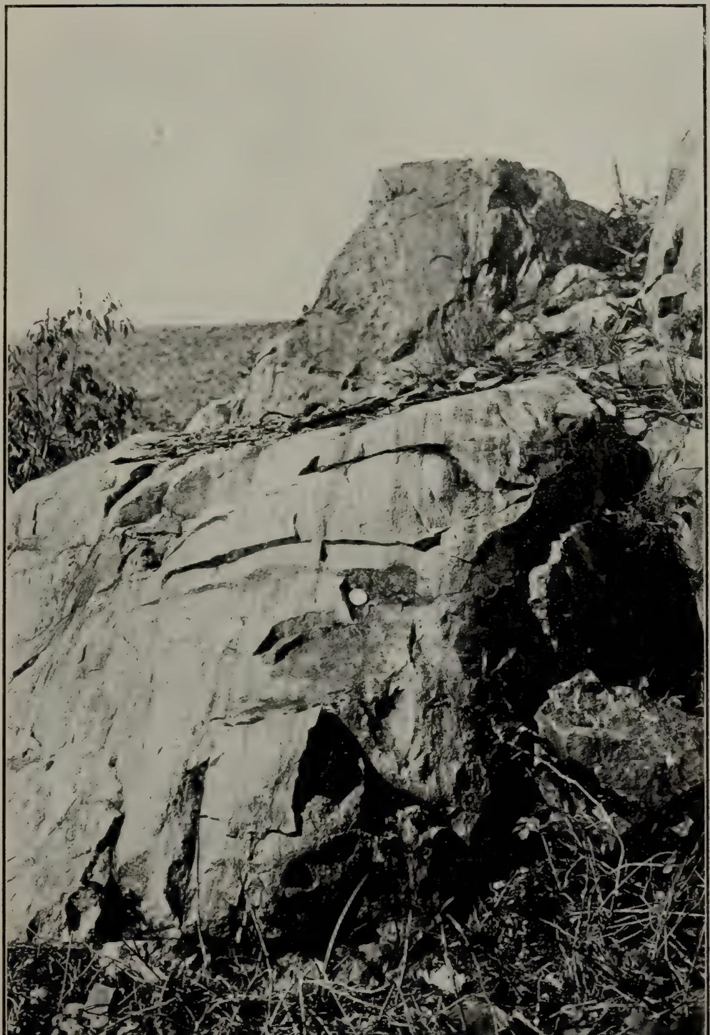
The thickness of the Temiskaming series cannot now be determined with certainty. In one locality it is known to be at least 7,000 feet.

LAMPROPHYRE DIKES AND LORRAIN GRANITE

Near Kirk lake, both lamprophyre and granite intrude the Temiskaming series, and the lamprophyre is seen to be older than the granite.

Lamprophyre dikes are numerous in the area. They are, for the most part, characterized by the prominence of hornblende, biotite or augite. The following types are probably present, viz.: minette, kersantite, vogesite and camptonite. The rocks vary in grain from fine to coarse, and in width from a foot to twenty feet or more. While they are somewhat disturbed, and in some cases much decomposed, they are usually massive rather than schistose, and frequently preserve their original textures.

The distribution of the Lorrain granite is shown on the map of Cobalt, scale one mile to an inch. The rock is a



Temiskaming series, tilted into vertical position, between Haileybury and New Liskeard.

coarse-grained, biotite granite, with a characteristic pink color. At Kirk lake it invades the Keewatin greenstone, the Keewatin iron formation (Grenville series), the Temiskaming sediments and the lamprophyre dikes. Whether some of the quartz and feldspar prophyries, described under the Keewatin series, are genetically connected with the Lorrain granite is not as yet known. The granite is overlain unconformably by the Cobalt series. Its relative age is therefore accurately known. Where it invades the adjacent formations it sends out in every direction many fine-to-medium-grained aplite dikes. In hand specimens these dikes are similar to some of the aplites which are the end phase of the Nipissing diabase. The latter dikes, however, contain only small quantities of potash, while the granite aplites at Kirk lake have normal percentages of soda and potash, as will be seen from the analyses given below. The intrusion of the Lorrain granite was probably the means whereby the Temiskaming sediments were tilted up into their present more or less vertical position. Near the contact the intrusion has sometimes developed garnets in the adjacent rocks.

Analysis No. 1, given below, is from the coarse-grained parts of the granite, while No. 2 is from the aplite dikes a few inches in diameter. In each case about a dozen specimens were taken in order to arrive at average results.

	1	2
SiO_2	71.86	76.03
FeO	2.34	1.29
Fe_2O_3	1.73	1.44
Al_2O_3	15.11	13.02
CaO	.51	.15
MgO	.43	.16
Na_2O	3.70	3.68
K_2O	3.48	3.74
H_2O	1.22	.96
	100.38	100.47

While the Lorrain granite has been intruded by the Nipissing diabase, silver-cobalt deposits of importance have not been found in it. That silver is rapidly deposited on the surfaces of or in cracks in the granite is shown by the

occurrence of this metal in veinlets which penetrate granite boulders in the Cobalt series, in the vicinity of the veins at the Coniagas and Trethewey mines. Certain dikes from the granite penetrate the Keewatin in the lower workings of the Temiskaming mine and are cut through by the vein. The granite is here coated with silver.

In the township of Lorrain, to the east of Cobalt, much of the granite presents a weathered surface, there being a gradual transition from the undecomposed rock to the overlying sediments of the Cobalt series.

THE COBALT SERIES

The age relations of this series of fragmental rocks are shown in the table on a preceding page.

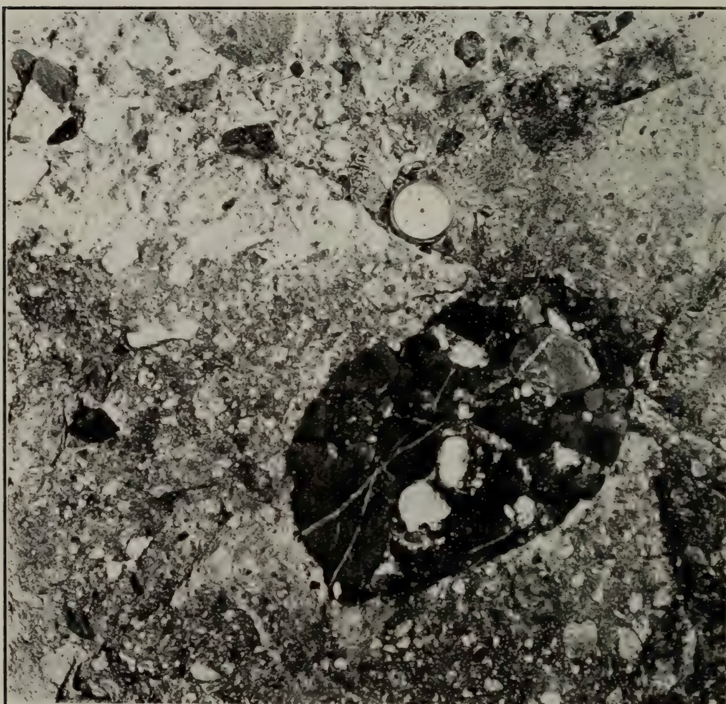
Since eighty per cent. or more of the ore mined at Cobalt has come from veins, or parts of veins, that are found in this series, it is the most important, from an economic point of view, of the rock groups of the area. Hence the name given to it is appropriate. The series also presents many other interesting features.

Erosion has left but remnants of this series, which in a past age covered practically all the surface in a vast region in Northern Ontario.

The series is wholly of fragmental origin, and contains rocks varying from those that are uniformly fine in grain to those that contain boulders several feet in diameter. The kinds of fragments composing these rocks are almost innumerable, representing as they do the erosive products from all the older pre-Cambrian series of the region—Keewatin, Laurentian, Temiskaming, Lorrain granite and intrusives of various ages. Naturally, fragments of the harder rocks and minerals have withstood better the destructive agencies to which they have been subjected, and the Cobalt series, especially the members of it that are coarser in grain, contain grains of feldspar and quartz, and pebbles and boulders of granite and other igneous representatives, in greater numbers than they do of minerals or rocks that weather or are abraded more readily. But representatives, as has already been said, of all the older rocks in the region are to be found in the form of pebbles or boulders as components of the Cobalt series.

BOULDERS COMPOSED OF CONGLOMERATE.

From the description of the Temiskaming series, on a preceding page, it will be seen that it, like the Cobalt series, consists of fragmental rocks, ranging from greywackés fine in grain to coarse conglomerates. Probably the most re-



Conglomerate of Cobalt series, containing a conglomerate boulder from the Temiskaming series.

markable boulders in the conglomerate of the Cobalt series are those of conglomerate from the Temiskaming series. If the latter series has furnished conglomerate boulders to the former, undoubtedly it has supplied pebbles or boulders of quartz and other minerals and rocks which once were constituents of its conglomerates.

Order of Deposition.

The surface of the region, in the period immediately preceding the deposition of the Cobalt series, was uneven, and possessed in all probability higher hills and deeper valleys than those of the present surface. Having been laid down on such an uneven floor, the series cannot be expected to show the same thickness of sediments everywhere, even had a great period of erosion not elapsed between the deposition of the sediments and the present time. Moreover, it would be expected that there would be a considerable variation in the order of succession of the sediments from those that lie at the base to those that form the upper members. While such variation in the thickness of the members of the series, and in their order of deposition, has been observed, as is shown in the following table, still, there is a pronounced definite order of deposition in the areas which have been studied by various workers throughout a wide region.

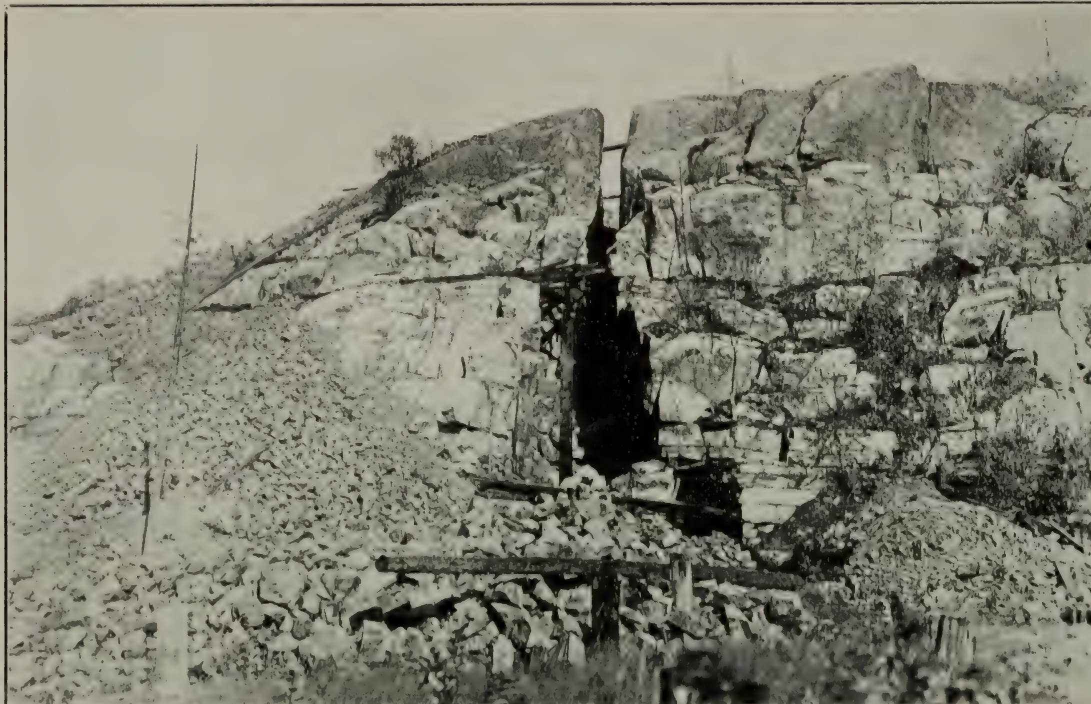
The following table shows the thickness of the Cobalt series at several characteristic localities, and the nature of the sediments, together with the order of deposition:

Wendigo Lake	Little Silver Cliff (Cobalt)	Mt. Chemaniss	Mt. Sinclair	Maple Mountain
				Arkose and quartzite (900 ft.)
Conglomerate*	Conglomerate (30 to 40 ft.)	Conglomerate (100 ft.)	Conglomerate*	
Greywacké and quartzite (26 ft.)	Quartzite (15 ft.)	Quartzite (135 ft.)		* * *
Quartzite (10 ft.)				* * *
Greywacké (54 ft.)	Greywacké (20 ft.)	Greywacké (315 ft.)	Greywacké (300 ft.)**	* * *
* * *	* * *	* * *	Conglomerate*	* * *
Total 90 ft.	70 ft.	550 ft.	300 ft.	900 ft.

*Thickness not given. **Greywacké contains occasional beds of slate and quartzite. ***Base of section is not exposed.

The arkose and quartzite of Maple mountain are considered to represent the Lorrain or upper part of the Cobalt series. This mountain contains the greatest thickness of sediments known in the region.

The exposure on the shore of the bay, on the east side of Lake Temiskaming, just south of Fabre wharf, may be cited as an example of a section where members of the series are absent. Here the upper conglomerate lies on the surface of the well-banded greywacké.



The Little Silver Vein, Nipissing mine. The cliff is about 70 feet in height, and is composed of almost horizontally lying rocks of the Cobalt series. At the bottom are probably several feet of coarse conglomerate, which is succeeded by about 15 or 20 feet of well banded slate-like greywacké. This is followed by about the same thickness of feldspathic quartzite, overlying which, at the top of the cliff, is a coarse conglomerate. The greatest thickness of the vein, as originally exposed, was about 8 inches. The strike is east and west, and the dip, as the photograph shows, is almost vertical. About $300,000 worth of ore was extracted from this vein.

Underlying Surface.

In the vicinity of Cobalt, the Cobalt series rests, characteristically, on a weathered surface of one or other of the older series of rocks. Most commonly the underlying series is the Keewatin, as rocks of this age are more widespread in the productive part of the area than are the other pre-Cobalt series. No surface that has the appearance of having been produced by glaciation is known beneath the Cobalt series in the vicinity of Cobalt.

Where the rocks of the Cobalt series rest on the greenstones or other easily decomposed members of the Keewatin there is a gradual transition from the non-disintegrated rock upward into the distinctly fragmental member of the Cobalt series. The disintegrated material on the surface of the Keewatin has been recemented and consolidated, or, in other words, recomposed. It is impossible at certain contacts, without the examination of thin sections under the microscope, to distinguish the recomposed material from the underlying massive igneous rock.

Something the same may be said of the contact between the upper members of the Cobalt series, the Lorrain arkose, and the Lorrain granite. In the township from which the name of these rocks is derived, arkose lies on the weathered surface of the granite, there being a gradual passage from the undecomposed rock upward into the arkose.

At the base of the Cobalt series there is the recomposed material described in the preceding paragraphs with, typically, conglomerate or breccia, many of the fragments of which can be seen to have originated in place. A striking example of the origination *in situ* of such material is to be seen on the shore of lake Temiskaming, on the extreme north end of lot 15 in the first concession of the township of Bucke, a couple of miles south of Haileybury. Here, as the geological map, scale 1 mile to 1 inch, shows, the Cobalt series forms a contact with the Keewatin. At the contact the Keewatin consists of greenstone, or basalt, and a dike of feldspar-porphyry. That the conglomerate and breccia of the Cobalt series, here resting on the Keewatin, has, for the most part at least, originated *in situ* is shown by the fact that it contains fragments of various

sizes of the porphyry dike. These fragments range in form from angular to sub-angular and rounded. Both the greenstone and the porphyry, but more especially the latter, show characteristic torsion cracks.

This contact and others in the district, between the Cobalt series and the older rocks, have a striking resemblance to those which have been described as existing between members of the pre-Cambrian, Torridonian and the older Lewisian, of the Northwest Highlands of Scotland. "The observer may climb one of these Archæan hills, following the boundary line between the Lewisian rocks and the younger formation, and note, step by step, how the subangular fragments of hornblende-schist that fell from the pre-Torridonian crags are intercalated in the grits and sandstones, thus indicating the slow submergence of the old land-surface beneath the waters of Torridonian time."*

" The basal breccias which often flank the buried mountains are, as already explained, of the nature of scree material. They consist of fragments of the local rocks embedded in a sandstone matrix. The conglomerates, on the other hand, are probably torrential deposits brought down from a district very different in geological structure from that of the area in which the Lewisian gneiss occurs."†

Slate-like Greywacké.

Normally, the basal conglomerate and breccia pass gradually upward into fine-grained, delicately banded, slate-like greywacké. The components of the graywacké are so fine in grain that they cannot be distinguished except by examination of thin sections under the microscope. When thus examined, they are found to consist, for the most part, of angular fragments of quartz and feldspar, which is usually quite fresh and undecomposed. The feldspar consists of orthoclase, microcline and the more acidic soda-lime varieties. Grains of glassy volcanic rocks, and of iron ore and other material, have also been observed. Chlorite and

*The Geological Structure of the North-West Highlands of Scotland, p. 4. Memoir of the Geological Survey of Great Britain.
†Idem, pp. 286-7.

other decomposition products are present. Under the microscope certain thin sections of the greywacké resemble volcanic ash. It has not been proved, however, that there was contemporaneous volcanic activity.

Typically, the slate-like greywacké has a greenish or greyish color, but in certain localities the color of the rock is distinctly reddish. The latter color is not found in the greywacké of the productive part of the Cobalt area proper, but reddish greywacké lies both to the west and to the east, outcropping in the western half of Coleman township, near Latchford on the Montreal river, and at two or three points near the shores of lake Temiskaming.

The greywacké, like the other members of the Cobalt series, lies usually in an almost horizontal position. Ripple or wave marks are frequently seen on the surface of its beds, *e.g.*, in the cliff at the Little Silver mine on the Nipissing property. Mud cracks have also been observed. While usually showing little evidence of disturbance, the greywacké is quite compact and does not split readily along the junction of many of the beds.

Normally, the greywacké passes upwards into quartzite, more or less impure, and the latter into conglomerate, but at times the quartzite is lacking and the greywacké is succeeded by conglomerate. Where the members of the series are complete, as at some points along the eastern shores of lake Temiskaming, the conglomerate appears to be succeeded without unconformity by what has been called the Lorrain arkose and quartzite, the latter of which is frequently interbanded with pebbly material.

At two or three places, however, where the upper members of the series, conglomerate or arkose, lie directly on the greywacké, without the quartzite or other intermediate member being present, the greywacké is seen to have been eroded before the deposition of the overlying rock.

Quartzite.

The quartzite usually has no great thickness, frequently being only twenty or thirty feet, but in certain localities impure quartzite or greywacké that overlies the delicately

Coarse boulder conglomerate, Cobalt series, Trethewey mine, Cobalt.

banded greywacké has a much greater thickness, as shown in the table on a preceding page.

At the Little Silver cliff, on the Nipissing property, the base of the Cobalt series is not exposed. Here there are fifteen or twenty feet of well-banded greywacké, overlying which there is about the same thickness of feldspathic quartzite. Above the latter is twenty or thirty feet of conglomerate.

At times the quartzite is interbanded with greywacké

Conglomerate.

What may be called the second conglomerate, to distinguish it from the conglomerate and breccia that lie at the base of the well-banded greywacké, or in other words the conglomerate that overlies the quartzite, is one of the most interesting members of the Cobalt series. The great variety of pebbles and boulders that are found in this rock give to it an appearance that attracts attention. It contains boulders representing practically all of the numerous older rocks of the region. Whether it represents a glacial deposit, or whether it is of torrential or other origin, in the opinion of many observers, is undecided.

The conglomerate of the Cobalt series is distinguished from that of the Temiskaming series chiefly by the fact that pebbles and boulders of pink granite, rather coarse in grain, are characteristic of the former and not of the latter. This is owing to the fact that the granites of the region, that antedate the Temiskaming series, are typically grey in color, while the pebbles and boulders in the conglomerate of the Cobalt series have been derived from the pink-colored Lorrain granite, which intruded the Temiskaming, but is older than the Cobalt series. Moreover, the members of the Temiskaming series dip at high angles while those of the Cobalt series are usually but slightly inclined.

Origin of the Conglomerate.

In the first edition of his report on the Cobalt area, concerning the origin of the conglomerate the writer said: "It is difficult to understand, for example, how certain

large boulders of granite in the conglomerate, which forms part of the highest outcrops of the Lower Huronian (Cobalt series), have been carried so far from their parent masses. These large boulders are found over much of the district, and there are now no outcrops of granite in the neighborhood of many of them. . . . In the present state of our knowledge we have little warrant for claiming that the granite boulders, often two or three feet or more in diameter and distant a couple of miles from exposures of the rock, indicate glacial conditions during Lower Huronian times, although we have no proof to the contrary."*

A couple of years after this report was published Dr. A. P. Coleman, while on a visit to the Trethewey mine, discovered striated boulders in the conglomerate in an outcrop on this property† that have all the characteristics of those which are found in glacial deposits. Hence, Dr. Coleman and other writers have decided that a certain part, at least, of the conglomerate of the Cobalt series is of glacial origin.

In the opinion of the present writer more evidence is required before the glacial origin can be accepted. Although for many years conglomerates similar to those of Cobalt have been studied over a vast extent of territory in northern Ontario, no glaciated surface on the rocks underlying this conglomerate has been discovered. During the last few years several workers in the Cobalt and surrounding areas have diligently searched for such a surface, but without success. The underlying rocks present, characteristically, a weathered surface, there being no sharp line of division between the underlying, undecomposed, or non-disintegrated, rock and the overlying fragmental rock. The glacial origin of the Cobalt conglomerate cannot therefore be proved so clearly as it can for similar rocks in other parts of the world. The Dwyka of South Africa, for example, rests on rocks that frequently show undoubted evidence of having been smoothed by glaciers. Opportunities for observing contacts at Cobalt are, however, being constantly enlarged

*Fourteenth Report, Bureau of Mines, Ontario, Part II., page 43.

†Am. Jr. Science, March, 1907. Journal of Geology, February-March, 1908.

by stripping the surface in prospecting, and it is possible that the Cobalt series may be found to rest on a surface of a different character from those at present known.

A glacial origin was at one time suggested for certain breccias or conglomerates in the Torridonian of the North-western Highlands of Scotland. In the report on that region, published a few years ago, this suggested theory of origin has been discarded.* "From the nature of the rocks it may be inferred that the conditions of deposit were probably those of a rapid accumulation in shallow water near a shore line, subject to violent currents and the influx of flood or stream-borne materials, with occasional intervals of quiescence during which the finer sediments were laid down. . . . In one instance, on the north side of Loch Maree, it has been observed that the blocks in the conglomerate have come from the hornblende-schist ridge of Ben Lair, and may have travelled a distance of three miles."

That surfaces on rocks resembling closely those produced by glaciers can be formed by other means is shown by the observations of Dr. E. O. Hovey.* In speaking of the accumulation of volcanic material on the side of Mt. Pelée, he says: "From time to time the coat of new material became water-soaked from the heavy tropical rains and slid down the mountain in more or less of a sheet avalanche. On the collecting ground of the steep upper cone, planation and grooving were not prominent, but on the middle ground of the Morne Saint Martin, where the force of the avalanches spent itself, planation and grooving were pronounced. In June, 1902, the striated surface of the old agglomerate, with here and there a heap of unassorted ash upon it, suggested closely the appearance of a regularly glaciated surface with its overburden of till."

Dr. Hovey says further: "Where the crevicing of the rock-mass has been favorable, the impact of stones hurtling down the stream bed has broken off chips from the bed rock, producing a good imitation of the 'chatter' marks made by a glacier."

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*The Geological Structure of the North-West Highlands of Scotland, pp. 23 and 273. Memoirs of the Geological Survey of Great Britain, 1907.

*Striations, U-shaped valleys, and hanging valleys produced by other than glacial action. Geol. Soc. Am., Vol. 20.

If such surfaces are thus produced, undoubtedly the faces of pebbles and boulders in moving masses of rock are also grooved and striated in such a way as to be undistinguishable from those of glacial origin.

Lorrain Arkose and Quartzite.

As explained on a preceding page the arkose and quartzite, to which the name Lorrain has been applied, are here grouped with the Cobalt series, and are considered to represent the upper members of the series. In two or three localities, the arkose and quartzite have been found to be unconformable to the slate-like greywacké or other lower members of the series, but in other places there is no evidence of an erosion interval. Since, however, the arkose and quartzite in most of the areas that have been mapped tend to occur distinct from the lower members of the series they are distinguished on the maps, by a different color, from the latter.

Frequently the arkose is found on the surface of granite, e.g., in the township of Lorrain, and is the decomposition product of the latter rock, there being a gradual passage from the undecomposed rock into the arkose. There is, moreover, a gradual passage upward from the arkose, first into impure quartzite, then into a purer quartzite and conglomerate, composed chiefly of quartz pebbles.

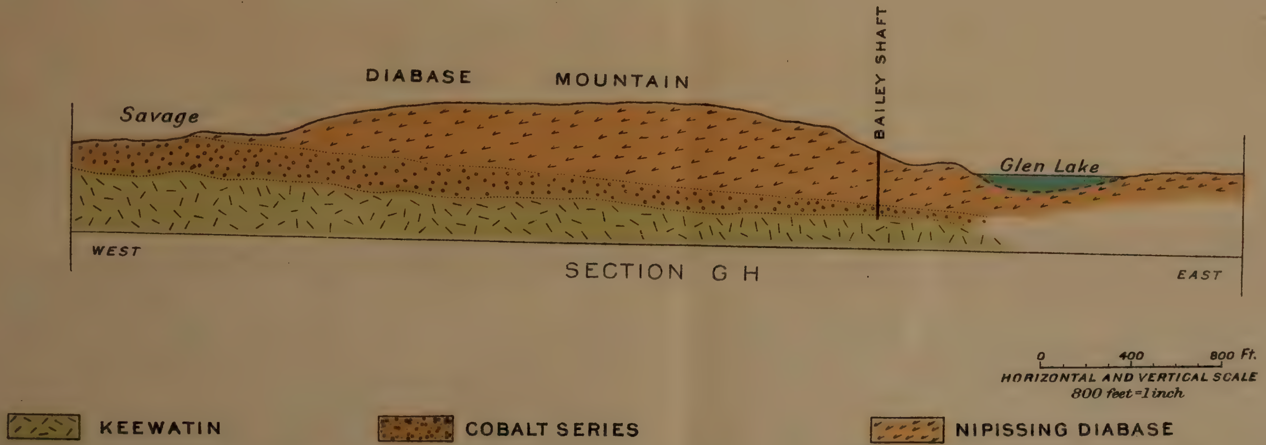
THE NIPISSING DIABASE

The diabase, to which the name Nipissing has been given, occurs characteristically as a sill. At Cobalt much of the hanging wall of the sill has been removed by erosion, and the diabase occupies about one-half of the surface of the productive area, the sill dipping on the whole at a low angle to the southeast. From following descriptions, however, it will be seen that the dip of the sill is much steeper at certain points.

In the region 5,000 square miles or more in extent, that surrounds Cobalt, the diabase occupies a considerable percentage of the area, and is seen in many cases to be in sill-like form. Owing to the association of cobalt ores with

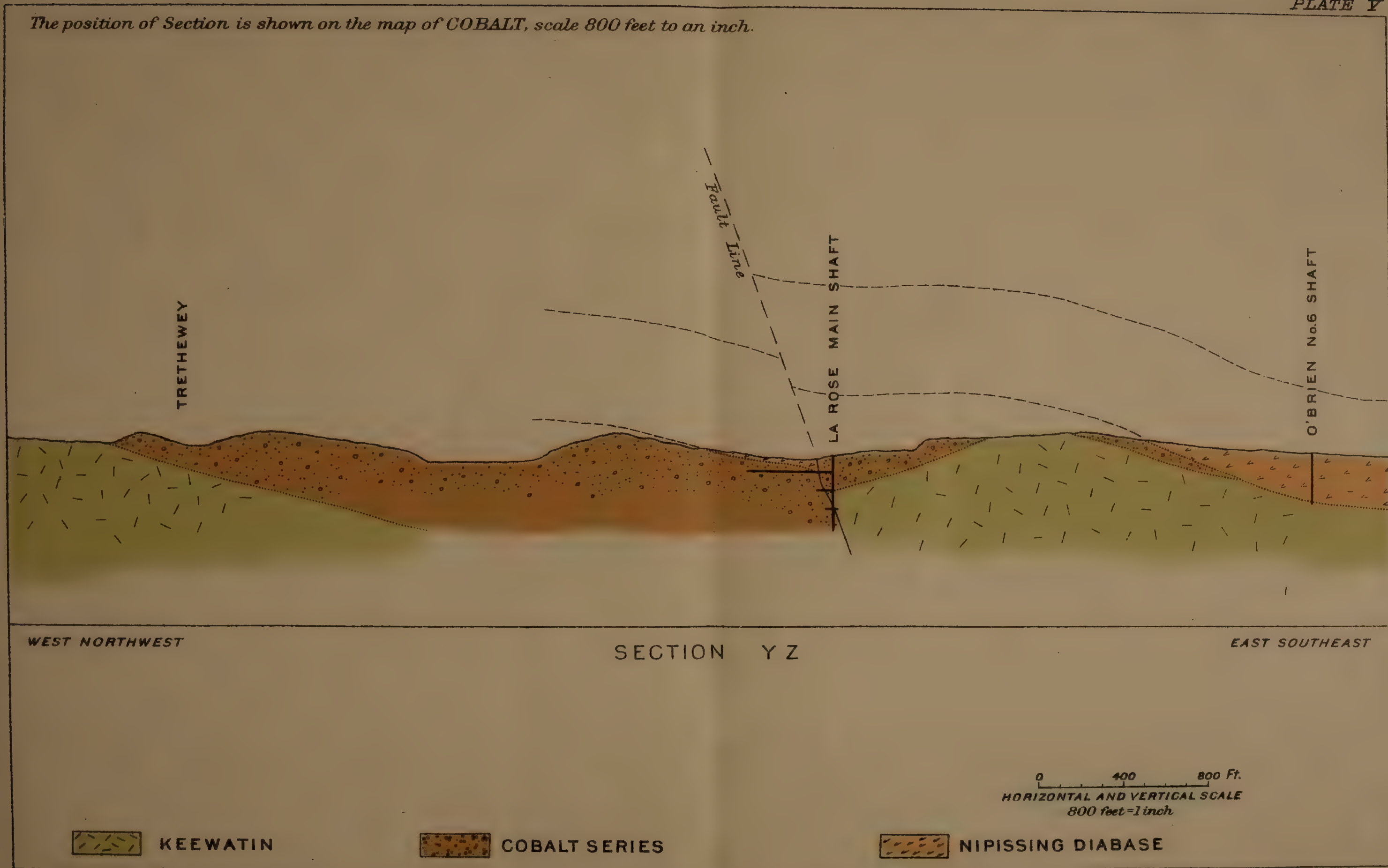
The position of Sections is shown on the map of COBALT, scale 800 feet to an inch.

PLATE II



To accompany Fourth Edition of Report by WILLET G. MILLER, Provincial Geologist, on the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming.
In Part II. of the Nineteenth Report of the Bureau of Mines, Ontario.

PLATE V



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this diabase in numerous localities throughout this region, the diabase and the ores are believed to have come from the same magma.

Nearly all varieties of the rocks forming the sill at Cobalt, when examined in thin sections, are found to have an ophitic texture, and primary quartz is almost always present. The rock is, therefore, a quartz-diabase. Most of the quartz is associated with feldspar in micrographic intergrowth.

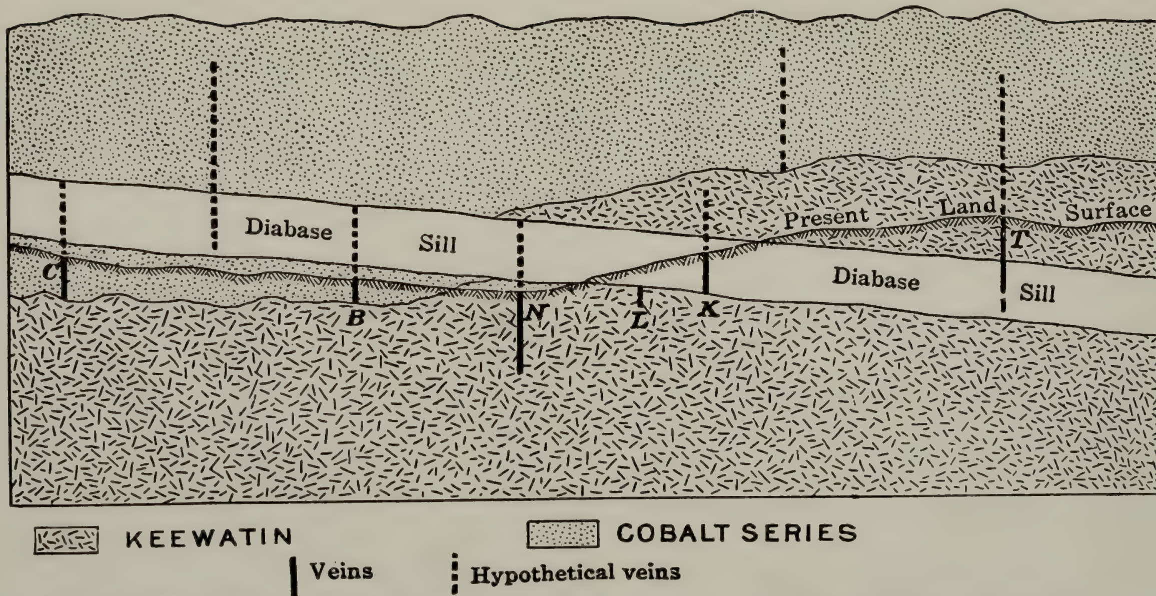
The chemical composition of certain typical specimens of the quartz-diabase of the Cobalt area, and its relation to the quartz-norite of Sudbury are shown in a following table.

The thickness of the diabase sill at Cobalt is five or six hundred feet or more. In diamond drilling, at one point near the shore of Cross lake, the thickness was found to be nearly twice as great, but this is believed to be due to faulting. Cross lake lies in line with Kirk, Chown and Goodwin lakes, the chain of lakes probably indicating the direction followed by a fault.

The accompanying generalized section shows the relation of the diabase sill to the Keewatin and the Cobalt series, and to the veins, in the Cobalt area. Cross-sections of the area published by the Ontario Bureau of Mines give more details, as the following notes on the general section of the area show. The "Map of Cobalt Area," scale 800 feet to 1 inch, that accompanies this guide book, shows the location of the sections.

General Section, Upper Half of Plate IV.

The section incorporates much of the information contained in other sections, together with additional data. Its total length is about 4½ miles, and it may be added that the bottom line represents sea level. The cross-section begins at the southeast corner of Sasaginaga lake, and shows the important area of conglomerate, greywacké, etc., of the Cobalt series, resting in an ancient valley of the Keewatin series, between Cobalt and Sasaginaga lakes. A reverse fault—normal to the line of section—occurs parallel to the longer axis of Cobalt lake, and it is also found at the McKinley-Darragh about one-quarter of a mile to the southwest, and at La Rose at the north end of the lake.



GENERALIZED VERTICAL SECTION THROUGH THE PRODUCTIVE PART OF THE COBALT AREA.

The section shows the relations of the Nipissing diabase sill to the Keewatin and the Cobalt series, and to the veins. The eroded surface is restored in the section. The sill is less regular than the illustration shows it to be.

B and C represent a large number of veins that are in the fragmental rocks, Cobalt series, in the lower or foot wall of the eroded sill. N represents a type of vein, such as No. 26 on the Nipissing, in the Keewatin below the eroded sill, and L a type such as one under Peterson lake, in the Keewatin foot wall, but not extending upward into the sill; K, a vein in the sill itself, such as No. 3 on the Kerr lake property; T, a vein such as that on the Temiskaming or Beaver properties, in the Keewatin hanging wall and extending downward into the sill.

At La Rose mine the rocks on the west side of the fault have been carried down a vertical distance of 210 or 220 feet, and at the McKinley-Darragh a vertical distance of at least 250 feet.

The diabase at the Little Nipissing dips S. E. at an angle of 16 degrees, while at the Crown Reserve it has been proved to dip more steeply at angles varying from 17 to 45 or 50 degrees to the N.W., from which it appears that the sill occupies a basin-like depression in the underlying rocks between these two properties.

If the Kerr lake area be now studied it will be found that the diabase inclines steeply to the N.W. and to the S.E. of the axis of the lake, forming a saddle-like structure. It may be seen dipping to the N.W. at the following points: the southwest shore of Cross lake; the northeast corner of the north Drummond lot; about 200 yards east of Kerr lake and 25 yards north of the road (a diamond drill hole near here has also proved the dip to be northerly); a trench on the Silver Leaf has exposed the contact of the diabase for about fifty yards or more. On the south flank of this saddle-like structure the diabase has been proved to dip S.E. at the following points: the Valentine shaft; a vertical diamond drill hole on the south part of the south Drummond lot; shaft No. 5 of the Drummond mine; shaft No. 1 of the Hargrave; two drifts from the No. 3 shaft of the Kerr lake; a drift from the 369-foot level of the No. 3 shaft of the Hargrave. From the above data it is thus seen that the saddle-like structure of the diabase at Kerr lake has been proved at several points. But it may be added that some of the steep inclinations of the sill may be partly due to faulting. There is, for example, a well defined fault in the diabase at the Crown Reserve, 540 feet north of the shaft in the drift at the first level, dipping 15 or 20 degrees to the north. Again on the south side of the saddle-like structure a fault, dipping to the southeast, was encountered at the Hargraves and Drummond.

At the Lumsden a shaft was sunk in the Keewatin to a depth of 290 feet, where it passed into the Nipissing diabase, proving that the sill here dips beneath the Keewatin greenstones at an angle of about 26 degrees. Similar relations are known to obtain at other points along the same contact to the southwest as far as Mount Greywacké

Coming, finally, to the Temiskaming mine it is found that the diabase has been encountered on the fourth and fifth levels, and at a depth of 575 feet in the main shaft. The surveys show that the sill dips at angles varying from 17 to 30 or 40 degrees in different parts of the mine, but it is probable that faulting may have caused some of the steeper inclinations, because a vertical fault between the diabase and Keewatin is known to occur on the fourth level. There are, however, no data at present to determine the throw of this fault.

Quartz-diabase, Cobalt, showing labradorite, P, embedded in a micrographic intergrowth of quartz and feldspar.

Facies of the Diabase.

While, as will be seen from the preceding descriptions, the diabase in the productive part of the Cobalt area is fairly uniform in character, differentiation is found in the outlying areas. Thus, a few miles to the west and also to the south of Cobalt pink spots, areas of micropegmatite, appear in the diabase. In certain localities these pink spots increase until the rock becomes pink or reddish, and is then more correctly described as granophyre than as diabase. A similar, but more complete, change, from a basic, darker rock to a lighter colored, more acidic variety, is found in the norite of Sudbury.

At times the typical diabase passes into a rock much coarser in grain, that has been described as gabbro, but many of these coarser varieties, when examined closely, are found to have the ophitic texture.

DIKES OF APLITE OR GRANOPHYRE YOUNGER THAN NIPISSING DIABASE

Especially in the Elk lake and Gowganda areas the Nipissing diabase is frequently cut by narrow dikes of aplite or granophyre. The material in these dikes is believed to represent residual, more acid material of the diabase magma. On the cooling of the diabase, cracks were formed in it, and material from the residual magma, rising through the cracks and fissures, formed the dikes of aplite or granophyre. Chemical and microscopical examinations of these dike rocks show that they are genetically connected with the diabase rather than with granite. Compared with the fine-grained granite or felsite dikes in the region, such as those connected with the Lorrain granite, the aplite dikes associated with the Nipissing diabase are found to be characteristically high in soda and low in potash, as following analyses show.

At Cobalt there is a dike of granite on the property of the University mine that cuts the Nipissing diabase and from its chemical composition is seen to be related to the aplites of Gowganda and Elk Lake. Having a much greater width than have the characteristic dikes elsewhere in the region, it is naturally coarser in grain. An analysis of samples from this dike is given below.

Examined in thin sections under the microscope, the dike rock at the University mine is found to be made up of feldspar, quartz and a colored constituent. The feldspar predominates, and consists of microcline and an acid plagioclase showing fine albite twinning lamellæ. The quartz and feldspar occur in allotriomorphic grains, but in two instances show distinct micrographic intergrowths. The colored constituent is not abundant; it was apparently originally a mica, but is now represented by chloritic material.

This dike averages fifty feet in width, while the dikes of the Montreal river area and Gowganda are usually under eighteen inches.

Analyses of the Acid or Granophyric Facies of the Eruptives

—	I	II	III	IV	V
SiO_2	72.33	62.54	61.93	67.76	76.03
Al_2O_3	12.99	14.79	13.03	14.00	13.02
Fe_2O_3	0.00	0.00	0.56	0.00	1.44
FeO	2.50	8.49	8.00	5.18	1.29
MgO	0.97	2.08	1.76	1.00	0.16
CaO	1.73	1.49	4.02	4.28	0.15
Na_2O	7.60	6.27	3.18	5.22	3.68
K_2O	0.00	1.12	2.80	1.19	3.74
H_2O	1.09	3.51	1.95	1.01	0.96
TiO_2	0.74	0.00	0.84	0.46	0.00
P_2O_5	0.00	0.00	0.32	0.19	0.00
MnO	0.00	0.00	0.18	trace	0.00
CO_2	1.00				
S	0.00	0.00	0.19	0.00	0.00
	100.95	100.29	98.76	100.29	100.47

I. University mine dike, Cobalt, N. L. Bowen, analyst (Journal Can. Min. Ist., Vol XII).

II. Lost Lake granophyre, Gowganda Cobalt-Silver area, N. L. Bowen, analyst,

III. Acid edge of nickel eruptive Onaping section, Sudbury, E. G. R. Ardagh, analyst.

IV. Near acid edge of the Blezard-Whitson lake section. Sudbury, T. L. Walker analyst.

V. Lorrain granite dikes, fine in grain or aplitic, Cobalt. About a dozen specimens were taken to get an average.

Analysis No. V is added to the table to show the difference in composition between the dikes of Lorrain granite and the acid facies of the Nipissing diabase and Sudbury norite. In all the analyses of the latter the proportion of soda to potash is high while in the case of the Lorrain granite dikes it is more nearly equal.

BASIC DIKES YOUNGER THAN NIPISSING DIABASE

In the region one hundred miles in width, between Sudbury on the southwest and Quinze lake, which lies to the east of the head of Lake Temiskaming, on the northeast, basic dikes have been found at many points. These dikes are younger than the Sudbury norite and the Nipissing diabase, which, of the basic igneous rocks, immediately precede them in age.

The age relation of these dikes to those of aplite or granophyre, described in a preceding paragraph, which are believed to represent acidic, residual material of the Nipissing diabase magma, is not known. The basic dikes in all probability also came from this magma. In the Sudbury area these dikes are cut by greyish, fine-grained granite, the youngest intrusive of that area.*

*14th Report, Ontario Bureau of Mines, Part III., pp. 14, 126.

At Sudbury the basic dikes are composed of olivine diabase which on weathering shows the characteristic spheroidal forms. In thin sections under the microscope the rock is one of the most beautiful of its class. Similar dikes of olivine diabase on the Quinze river, a hundred miles to the northeast of Sudbury, have been described by the writer*

In the region between Sudbury and the Quinze many dikes of olivine diabase have been found as well as those of olivine-free diabase.

In the vicinity of Cobalt these dikes are rare, the only one studied by the writer being the basalt-diabase of Cross lake.

Analyses.

The following table shows the chemical composition of two typical samples of the Nipissing diabase at Cobalt, and that of a rather basic type of the Sudbury norite, together with analyses of two later basic dikes.

——	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
SiO_2	45.20	47.22	49.84	48.06	49.90
TiO_2	....	3.62	....	....	1.47
Al_2O_3	19.08	16.52	18.94	18.23	16.32
Fe_2O_3	3.64	3.32	1.51 }	9.57	....
FeO	14.64	12.40	6.40 }		13.54
CaO	7.89	9.61	10.32	11.55	6.58
MgO	4.98	3.33	7.39	7.80	6.22
BaO	....	.01	....	....	....
Na_2O	3.32	3.40	1.99	1.87	1.82
K_2O	1.08	.67	1.28	.27	2.25
MnO	....	.04	....	....	trace
CuO	....	trace	....	....	....
NiO	....	.0275	....	....	....
CoO	....	.0055	....	....	....
P_2O_5	....	.33	....	....	.17
H_2O	....	.30	....	....	.76
Loss on ignition	....	....	2.57	3.54	....
Total	99.83	100.803	100.24	100.89	99.03
Sp. Gravity	....	3.01	....	....	....

No. 1, basalt-diabase dike, Cross lake, Cobalt. No 2, olivine diabase dike, Sudbury. No. 3, Nipissing diabase cut by basalt-diabase dike at Cross lake. No. 4, Nipissing diabase, on the Violet property near Cross lake. No. 5, norite, more basic than the average, at Sudbury.†

*11th Report, Ontario Bureau of Mines, pp. 227, 229.

†Analyses Nos. 2 and 5 are taken from Dr. A. P. Coleman's paper in the Fourteenth Report, Ontario Bureau of Mines, Part III.

PALEOZOIC

It will be seen from the map, scale 1 mile to the inch, that the Niagara and Clinton limestone forms some large outcrops on the islands and in the vicinity of the shore near the northwest corner of lake Temiskaming. This limestone affords stone suitable for building and for the production of lime, and on this account should be of considerable value in the years to come, since the rock is a somewhat rare material in most of this northern part of Ontario. The district to the west and north is being rapidly settled and will soon contain a large population which will need much material for building purposes. The following is an analysis of a sample of limestone taken from Farr's quarry, Haileybury:

	Per cent.
Insoluble residue	1.60
Ferric oxide and alumina	.66
Lime	29.50
Magnesia	21.59
Carbon dioxide	46.84
Sulphur trioxide	.70
	100.89

This limestone formation extends northward, although overlain by clay and similar deposits in many places, and has been observed by the writer along the south branch of the Blanche river below what is known as the Mountain portage.

Considerable attention has been paid to the limestone area, Sir William Logan having first described it years ago. It has been shown that the series here is more closely related to the Niagara of Southern Ontario than it is to the Niagara areas to the north and west.

The cobalt-silver deposits being of pre-Cambrian age, the Paleozoic limestone is of little interest in connection with the ores. It is of course possible that ore-bearing rocks underlie the limestone.

Along the wagon road, in lots 5 and 6 in the third concession of the township of Dymond, to the northwest of the town of New Liskeard, the limestone cliff presents a striking

face, indicating faulting. The fault line is continuous with the western shore of lake Temiskaming, and furnishes still further evidence confirmatory of the theory that the lake lies along a great northwest-southeast fault.

In places these limestones are rich in fossils.*

PLEISTOCENE

Immediately preceding the Glacial period, doubtless the surface of what is now the productive cobalt-silver area was in a highly weathered or decomposed condition. The glaciers scraped off the loose material from the surface and carried it southward, intermingled with other material. In all probability much more cobalt-silver ore was carried away by the ice sheet than has been mined. Nuggets or boulders of rich silver ore have been found in prospecting trenches at numerous points to the south of the mines. A glacial boulder, worth about five thousand dollars, is now in the Bureau of Mines collection.

Everywhere throughout the region the surfaces of the rocks give evidence of glacial action. The underlying loose deposits, on the surface of the glaciated rocks, consist typically of boulder clay. This is succeeded upward, north of Cobalt, by a considerable thickness of strikingly well laminated clay. Above this clay, on some of the hills, to the north of lake Temiskaming are sand and gravel deposits. The glacial deposits in this part of Ontario have been well described by Dr. A. P. Coleman.**

A couple of miles northward of Cobalt station the agricultural region of this part of northern Ontario is met with. The soil is essentially a well banded clay. Between this point and the height of land, or watershed, between the Hudson bay and Ottawa river waters, the clay does not form a continuous mantle, but there are large areas of tillable land which is being rapidly settled. Outcrops of solid rock, in many cases representing hill tops, which project through the clays, are seen. North of the height of land, however, is a large agricultural area, estimated at 16,000,000

*Geol. Sur. Canada, Vol. X, 1897.

**Lake Ojibway; Last of the Great Glacial Lakes. Eighteenth Report, Ontario Bureau of Mines, p. 284 *et seq.*

acres, now traversed by the National Transcontinental Railway, and known as the "great clay belt," in which exposures of solid rock are few in number. The clay on both sides of the height of land is pretty uniform in character.

Following is an analysis of the clay in a cut on the railway between Haileybury and New Liskeard. It will be seen that the lime and magnesia are rather high. This is owing to alternate bands containing considerable marl. The clay effervesces strongly in acid.

	Per cent.
Silica	52.00
Alumina	16.11
Ferric oxide	4.69
Lime	8.26
Magnesia	4.10
Potash	1.74
Soda	2.76
Sulphur trioxide	.09
Loss on ignition	9.64
Total	99.39

THE COBALT-SILVER VEINS.

The cobalt-silver veins occupy narrow, practically vertical fissures or joint-like cracks in rocks of three ages, viz.: Cobalt series, Keewatin series and Nipissing diabase. The relations of the veins to each of these three groups of rocks are shown in the accompanying generalized cross-section of the Cobalt area and in the larger scale, colored cross-section, (plate IV), published by the Ontario Bureau of Mines. The veins are much more numerous in the rocks of the Cobalt series than in the Keewatin or Nipissing diabase.

It was estimated that up to July 1st, 1911, the yield from the Nipissing diabase had been approximately 7.55 million ounces from 12 veins, or 629,000 per vein, or 7 per cent. of the total production. The Keewatin with 13 veins had produced 11.7 million ounces, or nearly 1 million per vein, or 10.85 per cent. of the total. From 86 veins in the Cobalt series there had been obtained 88.55 million ounces, or a

little over 1 million ounces per vein, representing 82 per cent. of the total production. It is difficult to determine the exact number of productive veins owing to the fact that, being very narrow, parts of one vein may be mistaken for two or more distinct veins. At the present time there are 115 or more productive veins, and the relative productivity of those in the three series of rocks is about the same as it was in 1911.

A typical silver-cobalt vein, outcrop on Coniagas, Cobalt. The head of the hammer shows the width.

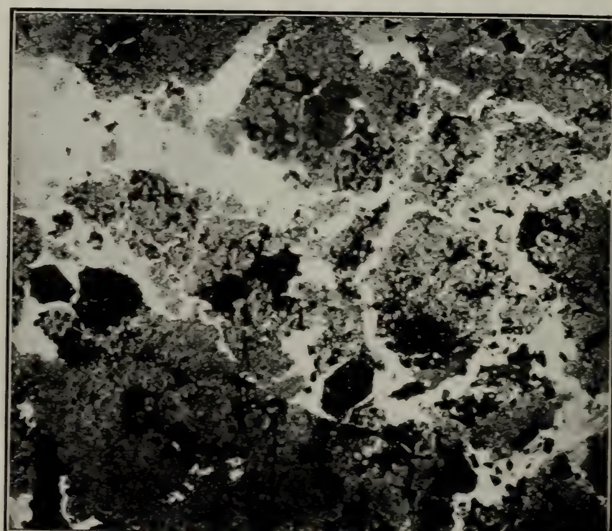
ORIGIN OF THE VEINS.

After the intrusion of the Nipissing diabase sill, which, on the whole, dips at a low angle from the horizontal, and pentrates both the Cobalt series and the Keewatin, disturbance, probably due chiefly to the contraction of the sill on cooling, caused fissures and joint-like cracks to be formed. These openings were made in the rocks of the hanging-wall of the sill, in those of the foot-wall, and in the sill itself.

Ore-bearing waters working through or along the zone of weakness produced by the sill deposited their burden in the fissures and cracks. The minerals first to be deposited were essentially cobalt-nickel arsenides, and related compounds, and dolomite or pink spar. The fissures and cracks

were ultimately filled with these minerals. Then there was a slight disturbance of the veins, reopening the ore-filled fissures and cracks, or facturing the material deposited in them.

In the interval, between the filling of the fissures and cracks with cobalt-nickel ores and the fracturing of the veins thus formed by a secondary disturbance, the character of the material carried by the circulating waters had changed. Silver was then the characteristic metal in solution and it was deposited, along with calcite, in the



Polished surface of silver ore, slightly magnified, from La Rose mine, Cobalt. The native silver, S, is the white material in the illustration. The large black patches are calcite, the small black spots niccolite, and the grey is smaltite.

cracks and openings in the fractured veins. There may have been some silver deposited in the earlier period of vein filling and doubtless cobalt-nickel minerals were deposited after the secondary disturbance, but the latter minerals belong characteristically to the first generation and the silver minerals to the second.

Certain writers on the Cobalt ores have expressed the opinion that the silver represents "secondary enrichment," meaning that it has come from the decomposition of com-

pounds of the metal in the veins that were deposited at approximately the same time as the cobalt-nickel minerals. The present writer believes that at least by far the greater part of the native silver is of primary origin. The recent interesting experiments of Messrs. Chase Palmer and Edson S. Bastin,* on the precipitation of silver from solutions by cobalt-nickel minerals, appear to confirm the opinion that the native silver is a primary deposit, and did not come from the decomposition of silver compounds in the veins. The work of these gentlemen shows that where silver solutions come in contact with cobalt-nickel minerals the silver is deposited rapidly and essentially as native silver. Since there is much calcite in the veins with the native silver, it would appear that the metal was carried in solution as a carbonate, or double carbonate. Under ordinary conditions of temperature and pressure, silver carbonate is slightly soluble in water. For example, sufficient of the carbonate can be dissolved in an ordinary beaker of water to make a distinct precipitate of metallic silver when cobalt-nickel minerals are placed in the beaker.

It has been proved, by the experience gained in mining at Cobalt, that the presence of rich silver ore is dependent on proximity to the diabase sill. Over much of the productive area, not only the upper wall of the sill but the sill itself and more or less of its foot-wall have been removed by erosive agencies. Owing to little of the upper or hanging wall remaining in the productive area, most of the ore has come from the foot-wall of the sill, or from what was the foot-wall before erosion took place. In these veins, in the foot-wall of the sill, it is the exception to find rich silver ore extending more than two or three hundred feet below the surface. Most veins are productive to a lesser depth. After rich silver ore disappears, with increase in depth, cobalt-nickel ore frequently continues downward in the veins. This seems to be due chiefly to the strong precipitating effects that the cobalt-nickel minerals had on the silver in the waters that worked downward beneath or along the sill. The silver was deposited before it reached a great depth. In certain cases, where veins with cobalt-nickel minerals contain no rich silver ore, or in which the silver extends to

*Ec. Geology, March, 1913.

a comparatively shallow depth, the absence of the precious metal is to be accounted for by the fact that such veins, or parts of veins, escaped fracturing during the secondary disturbance, thus not affording openings for deposition from the silver-bearing solutions.

Frequently, below the rich silver-bearing parts of veins well crystallized argentite and hair silver are found in vugs. These minerals may represent secondary deposition

An underground view in La Rose mine, Cobalt, showing parallel veins.

of a little of the silver that has been dissolved from the upper part of the veins and carried downward.

Characteristically, the native silver of the area is impure, chiefly from the presence of antimony and mercury. Samples of well crystallized silver and certain veinlets of the mineral that have been examined are free from these impurities. Such silver is probably of secondary origin.

When native silver is precipitated by its solutions coming in contact with cobalt-nickel minerals, compounds of nickel

and other metals go into solution. Hence, it is not surprising to find in the Cobalt veins minerals or compounds of the baser metals that appear to have been deposited during the later period of vein filling.

FORMER VERTICAL EXTENSION OF VEINS.

Certain writers have expressed the opinion that veins of the Cobalt area, that outcrop at the surface or occur immediately below the drift covering, represent the narrower, lower parts of wider veins that extended to or towards the original surface. There is no justification for the holding of such an opinion. The few veins that have been worked to a depth of a few hundred feet in rock of one series give no indication of becoming narrower below, although, when the veins are in the foot wall of the sill, the ore tends to become less rich as the vertical distance below the sill or the eroded part of it becomes greater. Moreover, "blind" veins, or those which do not reach the present surface of the rock, have been found. These veins have the same character, as regards width and mineral content, as those which are exposed at the surface.

Briefly, it appears that after the intrusion of the diabase, fissures and cracks were formed in the rocks of the hanging wall and in those of its foot-wall, and in the sill itself. The openings in the upper wall probably extended a considerable distance upward beyond the sill, but there is no evidence that they reached the surface or that they were wider in the parts that have been eroded.

Some of these fissures in the upper wall extended downward into the sill itself, e.g., veins on the Temiskaming, Beaver, and Nova Scotia. The veins on these properties, worked at the surface in the Keewatin hanging-wall, and in the diabase sill below, are the deepest mines in the area. No foot-wall vein has been found to be productive to such a depth.

Then there are veins, e.g., that on the Cobalt Central property, which have been worked at the surface in the diabase and followed downward into conglomerate and greywacké which at times lie beneath the sill.

Again, blind veins are found in the Cobalt series and in the Keewatin where the sill has been eroded.

There are also blind veins, e.g., one that was worked two or three years ago under Peterson lake and one on the Silver Leaf property, that lie in Keewatin beneath the sill. These veins run upward to the lower face of the sill but not into it.

The types of veins mentioned in the preceding paragraphs are shown in the accompanying, generalized cross-section of the area.

RELATION OF WALL ROCK TO ORE.

The productive veins, as the maps and cross-sections show, are found in three series of rocks, viz.: the conglomerate and other sediments of the Cobalt series, the Nipissing diabase sill, and the Keewatin complex. But eighty per cent. or more of the ore has come from the Cobalt series. The chief reason for this greater productiveness is due to the fact that these rocks fractured more readily than did the diabase or the Keewatin.

There appears to have been no difference in the precipitation of ores due to physical-chemical influences of the country rocks. Precipitation seems to have taken place as readily in rocks of any one of the three series mentioned in the preceding paragraph as in the others.

Judging from the way in which silver is found in the minutest cracks in granite boulders of some of the conglomerate near the veins, this ore, at least, was precipitated no less readily in acidic rocks than in basic ones. With the exception of these boulders, there are few opportunities afforded of observing the relations of the ore to granite. But in the Temiskaming mine, a few hundred feet below the surface, narrow dikes of Lorrain granite intrude the Keewatin and are cut across by a vein. The surface of the granite is plated with native silver.

The occurrence of rich silver ore depends on the character of the openings in the rocks now occupied by the veins, on whether the veins have been affected by secondary disturbances, and on the proximity of the openings to the diabase sill. Naturally it would be expected that solutions would work upward through the openings in the hanging wall above the sill more readily than downward into the foot wall. Unfortunately owing to the excessive erosions to which the district

has been subjected, there is little of the hanging wall of the sill left in the productive area at Cobalt. But of the veins thus far worked the two or three that occur in the hanging wall are productive to the greatest depth reached in the area.

In the foot wall of the sill, or what was the foot wall before erosion took place, the rich or merchantable ore is limited as to the depth to which it extends. This depth below the sill is variable, depending on the character and strength of the fissures, and other factors already mentioned. Rich ore descends to a less depth in narrow more irregular fissures than in wide ones.

As has been said previously, much the greater part of the ore has come from veins in the fragmental rocks of the Cobalt series in the foot-wall of the sill. These veins, on reaching the contact of the Cobalt series with the underlying Keewatin, either end at the contact, or split into stringers, or continue down into the Keewatin. In many cases the rich ore disappears when the veins penetrate the Keewatin. On the other hand, a few veins in stronger fissures have been found to be productive in the Keewatin, that, before erosion, lay beneath the sill.

In the veins both in the diabase and Keewatin rocks, ore is found to occur more irregularly distributed than in those of the Cobalt series. In other words, it tends to occur in bunches.

The best veins that have been worked in the diabase are one on the Kerr lake property and one on the O'Brien. Of those in the foot-wall of the sill, the best vein in the Keewatin has been No. 26 on the Nipissing.

ORES AND MINERALS.

The more important ores in the veins under consideration are native silver—associated with which is usually some dyscrasite, argentite, pyrargyrite and other compounds of the metal—smaltite, niccolite and related minerals. Many of the minerals occur mixed in the ores, and for this reason some of them have not been clearly identified. Another character of the minerals, which renders their identification difficult, is the fact that most of them occur in the massive form. Crystals when present are small, being frequently almost microscopic in size. The following minerals have been identified and can be conveniently classed under the headings:

I.—Native Elements:

Native silver, native bismuth, graphite.

II.—Arsenides:

Niccolite, or arsenide of nickel, $NiAs$; chloanthite, or diarsenide of nickel, $NiAs_2$; smaltite, or diarsenide of cobalt, $CoAs_2$.

III.—Arsenates:

Erythrite, or cobalt bloom, $Co_3As_2O_8+8H_2O$; and annabergite, or nickel bloom, $Ni_3As_2O_8+8H_2O$; scorodite, $FeAsO_4+2H_2O$.

IV.—Sulphides:

Argentite, or silver sulphide, Ag_2S; millerite, or nickel sulphide, NiS; argyropyrite? stromeyerite? $(Ag, Cu)_2S$; bornite, Cu_5FeS_4; chalcopyrite, $CuFeS_2$; sphalerite, ZnS; galena, PbS; pyrite, FeS_2.

V.—Sulpharsenides:

Mispickel, or sulph-arsenide of iron, $FeAsS$; cobaltite, or sulph-arsenide of cobalt, $CoAsS$.

VI.—Sulpharsenites:

Proustite, or light red silver ore, Ag_3AsS_3; xanthoconite? Ag_3AsS_4.

VII.—Antimonides:

Dyscrasite, or silver antimonide, Ag_6Sb; breithauptite, $NiSb$.

VIII.—Sulphantimonites:

Pyrargyrite, or dark red silver ore, $Ag_3\,SbS_3$; stephanite, $Ag_5\,SbS_4$; polybasite? $Ag_9\,SbS_6$; tetrahedrite, or sulph-antimonite of copper, $Cu_8Sb_2S_7$; freibergite? (silver-bearing tetrahedrite).

IX.—Sulphobismuthites:

Matildite, $AgBiS_2$; emplectite, $CuBiS_2$.

X.—Mercury:

Amalgam?

XI.—Phosphate:

Apatite.

XII.—Oxides:

Asbolite; heubachite?; heterogenite?; arsenolite; roselite?

XIII.—Veinstones:

Calcite, dolomite, aragonite, quartz, barite, fluorite.

The table contains a few minerals that have been found in only one or two veins and cannot be considered characteristic. Millerite, for instance, is of rare occurrence, and emplectite has been found only in the Floyd mine, near Sharp lake, in the western part of the Cobalt area. Bornite, chalcopyrite, zinc blende, galena and pyrite are not characteristic of most of the ore, these minerals occurring more frequently in the wall rock or in non-silver bearing ore of the Keewatin, but one or two mines have produced copper with cobalt-silver ore. Apatite in recognizable crystals has been found in the ore of only one mine. Mercury appears to occur in the ore of all the mines that contain high values in silver, but whether it occurs only as amalgam or in other forms has not been determined. Among the veinstones, aragonite is found but rarely, at least in easily recognizable form, while barite and fluorite have not been observed in the veins at Cobalt proper.

A question mark has been placed after the names of several minerals in the table which have been reported to occur in the veins but the identification of which has not been made complete by chemical analyses or crystallographic measurements.

Gold in small quantity has been found in a number of veins, especially in those in which cobaltite or mispickel are characteristic minerals.

A characteristic of the group is the subordinate part which sulphur plays in comparison with arsenic. Antimony, which is not abundant, is found in some compounds where one would expect to find arsenic, since the latter is so much more abundant. For instance, while both native silver and arsenides occur in abundance, the compounds of arsenic and silver are found only in small quantity. Then one would also expect to find more compounds of bismuth since this metal occurs in the free state in considerable quantities in some parts of the deposits. It might also be expected that native arsenic would occur at times.

Nearly all the chemical groups of minerals found in the celebrated Joachimsthal deposits of Bohemia are present in the Temiskaming ores. The most important exception is uraninite or pitchblende, which came into prominence a few years ago on account of its being the chief source of the element radium.

ORDER OF DEPOSITION OF MINERALS.

The following table shows, in descending order from the youngest to the oldest, the general succession in the order of deposition of the principal minerals of the Cobalt area proper. There appear to be, however, minor exceptions to this order.

III. Decomposition products, e.g., erythrite or cobalt bloom, annabergite and asbolite.

II. Rich silver ores and calcite.

I. Smaltite, niccolite and dolomite or pink spar.

After the minerals of group I. were deposited the veins were subjected to a slight movement. In the cracks thus formed the minerals of group II. were deposited. A few veins that escaped the disturbance do not contain silver in economic quantity.

This order of deposition appears to be the same as that of the minerals in the Annaberg deposits of Germany and in those of Joachimsthal, Austria.* At Annaberg the uranium ore or pitchblende is said to have been deposited earlier than the rich silver ores and later than the cobalt-nickel minerals, while barite, fluorite and quartz were deposited prior to the latter. At Annaberg there are thus considered to have been broadly five periods of deposition, while at Cobalt there have been but three, minerals representing the first and third periods being absent.

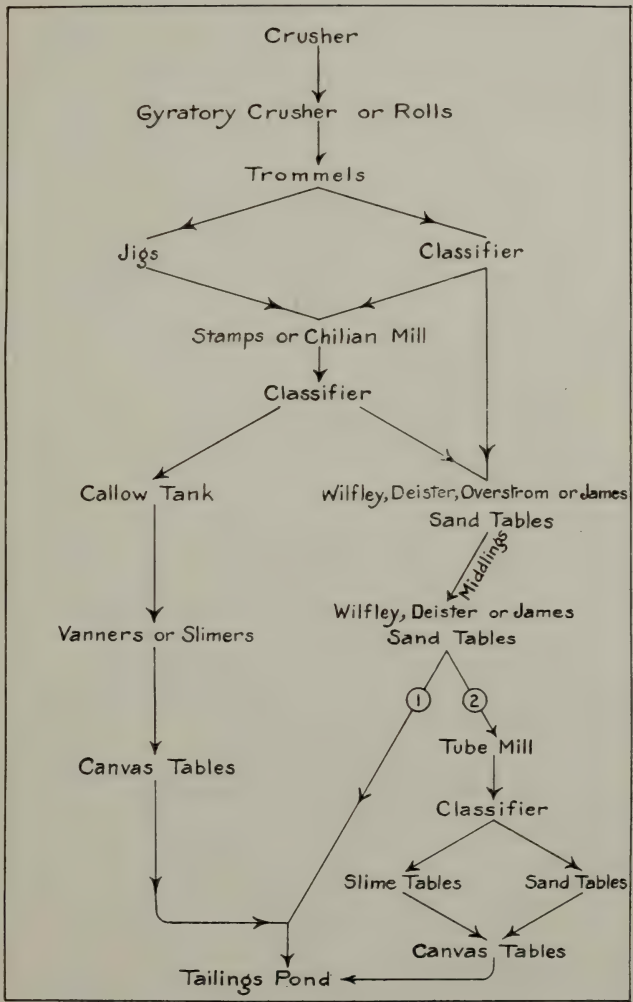
MINING AND MILLING.

Descriptions of the working mines, and of the methods employed in mining and milling, in the Cobalt area, are given in part I of the Annual Reports of the Ontario Bureau of Mines, and in the Annual Reports of Mr. A. A. Cole to the Temiskaming and Northern Ontario Railway Commission.

BIBLIOGRAPHY.

References to most of the literature on the Cobalt and adjacent areas are given in the report on the "Cobalt-Nickel-Arsenides and Silver Deposits of Temiskaming," fourth edition, published by the Ontario Bureau of Mines, Toronto, 1913.

*Beck, "The Nature of Ore Deposits," Weed's translation, pages 285, 289.



General flow sheet, Cobalt concentrators.

ANNOTATED GUIDE.

SUDBURY TO NORTH BAY.

Miles and Kilometres.

439.2 m. Just east of the station at Sudbury there is a
708 km. hill of gabbro. Beyond this a conglomerate, called the Ramsay lake conglomerate, outcrops all along the north shore of the lake for two miles. This conglomerate overlies a quartzite which occurs toward the easterly end of the lake.

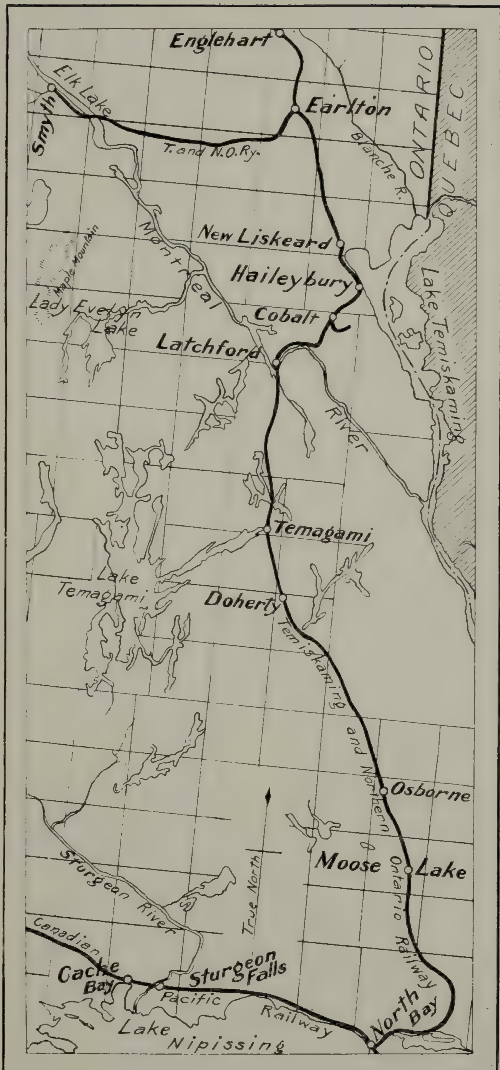
432.2 m. (Altitude 841 feet). The quartzite is well
697 km. exposed around Romford junction, showing the beds of the stratified rock dipping about 45 degrees S.

431. m. The Mond Nickel Company have erected a
695. km. copper-nickel smelter about one mile south of Coniston to treat the nickeliferous pyrrhotite ores from Victoria mines and other properties. Just east of Coniston a tongue of greenstone crosses the track.

427.1 m. (Altitude 799 feet). Near Wanapitei station
689. km. there is a contact of the quartzite and Laurentian gneiss to the east. This contact follows for some distance the northeast-southwest course of the Wanapitei river. Between Wanapitei and Sturgeon Falls the railway follows a series of valleys in the Laurentian. In these valleys are several towns about which there are small areas of good agricultural land. All the rock exposed along the railway east of Wanapitei is Laurentian gneiss.

383.3 m. (Altitude 687 feet). At Sturgeon Falls
618. km. the water power is utilized by a mill in the manufacture of pulp from spruce wood which is floated down the Sturgeon river. Reddish Laurentian gneiss is well exposed about the dam at the pulp mills.

360. m. (Altitude 654 feet). For a few miles west
580. km. of North Bay the railway skirts the north shore of Lake Nipissing, which is 90 miles long and 20 miles wide. Immediately west of North Bay the Laurentian is concealed by a covering of drift.



Route map between North Bay and Englehart

Miles: 10 0 10 20 30

Kilometres: 10 0 10 20 30 40 50

The town of North Bay (population about 8,000) is a divisional point on the Canadian Pacific railway, and also the southern terminus of the Temiskaming and Northern Ontario railway. Both the Grand Trunk and Canadian Northern railways have lines into the town.

ANNOTATED GUIDE.

NORTH BAY TO TEMAGAMI, COBALT AND HAILEYBURY.

Miles and Kilometres.

For 64 miles (103 km.) north of North Bay, as far as the station of Doherty, the railway crosses a monotonous succession of Laurentian gneisses, which in many areas are characterized by a strikingly banded structure. Generally speaking these gneisses may be said to consist dominantly of pink or light grey bands, and subordinately of dark-colored or black bands, all having the composition of granite, save some of the darker types. Regarding the age relation of the light-colored and dark-colored bands, it may be said that the former are seen in some cases to be intrusive into the dark bands, but that more often it is difficult or impossible to determine what the relation is. The dark bands are certainly in part elongated fragments of Keewatin greenstones. Both dark and light bands are injected by pink granite and pegmatite, either parallel with or cutting across the schistosity.

0.0 m.
0.0 km.

Leaving North Bay the elevation of which is 654 ft. (199.4 m.) the railway climbs a heavy grade for 21.5 miles (34.7 km.) reaching an elevation of 1,290 ft. (393.3 m.) above sea level, that being the highest point on the track in the 479 miles (772.5 km.) which separate Toronto from Cochrane. For about a mile (1.6 km.) from North Bay the banding of the gneisses is very striking. The darker bands contain biotite or hornblende. To the east of the railway for a few miles the gneisses become in

places thickly studded with garnets and they may then be referred to as garnet schists. These schists are often intricately contorted, and are similar to certain schists in Eastern Ontario which are commonly classed with the Grenville series.

10.1 m. Between mileage 1 (1.6 km.) and mileage
16.3 km. 10.1 (16.3 km.) the gneisses are much covered with superficial deposits, but pink, grey and brown types were noted, holding few dark bands.

What may be referred to as the Mulock gneiss occurs in the area about Mulock station,
18.0 m. altitude 1,222 ft. (372.6 m.). It is a coarse-
29.1 km. grained, pink biotite variety in places having a marked "augen" texture. This gneiss lacks the striking banding of the rocks at North Bay. Pink, light-colored gneisses with subordinate areas of the dark banded types occur between
27. m. mileage 21.5 and Tomiko, altitude 1,167 ft.
43.6 km. (355.9 m.). On the other hand the country between Tomiko and mileage 35 is underlain
35. m. by a banded, dark, glistening biotite gneiss, in
56.5 km. which pink gneiss is subordinate in amount.

47. m. For the next twelve miles, as far as the
75.6 km. station of Bushnell, altitude 996 ft. (303.5 m.), the rocks are poorly exposed, the last seven miles being covered by "muskeg."

56. m. Between Bushnell and Redwater, altitude
90. km. 1,015 (309.3 m.), a dark biotite gneiss first predominates; as Redwater is approached the dark bands become hornblendic and chloritic, one small lense held by the pink gneiss consisting largely of chlorite. This latter resembles a fragment of Keewatin greenstone schist. Both pink and dark gneisses are injected by granite pegmatites, cutting across or parallel with the bands.

A variety of granitic rocks occurs between
64. m. Redwater and Doherty, altitude 1,063 ft. (324
103. km. m.). Thus, for the first three miles north of Redwater pink gneisses predominate holding

subordinate areas of grey or dark gneiss. Between mileage 59 and 60 the rock is a massive red granite, gneissoid in part and not often banded. The next two and a half miles disclose banded gneisses, many of the dark bands of which are as basic as certain Keewatin hornblende schists. Between mileage 62.5 and 64 a coarse, massive, hornblende granite is well exposed. Dikes of fresh diabase, resembling the olivine diabase dikes of the Sudbury nickel area, are to be seen between mileage 56 and 64.

At Doherty, mileage 64, the first exposures of pre-Cambrian sediments make their appearance. A series of conglomerate, greywacké, and slate-like greywacké, resting in horizontal position, lie unconformably on the massive, hornblende granite last mentioned. This series of sediments, which is known as the Cobalt series, holds numerous pebbles and boulders of the underlying granite. Contacts of the conglomerate and granite occur at the railway station.

65.5 m.
105.3 km.
About one and one-half miles north of Doherty fine-grained hornblende schists of the Keewatin series are well exposed. These are cut by light-grey dikes of quartz or granite-porphyry. On the east side of the track the conglomerate of the Cobalt series rests on the upturned edges of the hornblende schists.

66. m.
106.1 km.
One-half mile farther north, outcrops of Nipissing diabase occur. This rock is widely distributed in Northern Ontario, and is of importance because of the fact that it is closely connected, genetically, with the phenomenally rich silver-cobalt veins which occur near the town of Cobalt, 36 miles (57.8 km.) to the north.

72. m.
115.8 km.
Between mileage 66 and Temagami, altitude. 989 ft. (301.3 m.), good outcrops of Keewatin schists and conglomerate of the Cobalt series are seen. South of Temagami grey sericite schists of the Keewatin series have resulted from the metamorphism of quartz-porphyries.

Temagami lake is one of the most beautiful sheets of water in Northern Ontario, a fact which caused the building of three summer hotels on its shores. The railway station lies at the east end of what is known as the North-east Arm of the lake. A few hundred yards north of the station conglomerate of the Cobalt series may be seen resting on the jagged edges of Keewatin greenstone schists. While to the west of the track about two hundred yards splendid outcrops of the Keewatin iron formation (jaspilyte) occur. The latter, which is 1,000 ft. wide in places, is easily reached by a foot-path, and consists of silicious magnetite inter-banded with variously colored jaspers and cherts, with in some instances a small proportion of hematite.

94. m.
151.2 km. Between Temagami and Latchford, altitude 922 ft. (281 m.), the railway passes successively over granite, conglomerate, slate-like greywacké, quartzite, diabase, and red, banded greywacké. The latter is well exposed on the cliffs bordering the railway south of Latchford.

98. m.
157.6. km. For the next four miles, as far as Gillies, altitude 934 ft. (284.6 m.), the railway closely follows the Montreal river, which empties into lake Temiskaming 21 miles to the southeast. At Latchford the river, which for the most part pursues a steady southeasterly course, bends sharply to the northeast until Gillies station is reached when it takes its normal direction again to the southeast. Below Gillies several miles, at Hound and Ragged chutes, important falls on the Montreal river have been utilized to supply compressed air and electric energy for the silver mines at Cobalt. At Ragged chute the air is compressed by a simple and ingenious hydraulic method, and is conveyed directly to Cobalt in a 24-inch pipe.

Leaving Gillies station the railway passes over Nipissing diabase, Keewatin greenstones, and conglomerate and greywacké of the Cobalt
103. m. series, to the town of Cobalt, altitude 973 ft.
165.7 km. (296.5 m.). The town is built on the west side of Cobalt lake, a small, narrow body of water about a mile in length. The population of the town, according to the census of 1911, is 5,638.

107. m. There is a steady descent of the railway for
172.1 km. about four miles to the town of Haileybury, altitude 766 ft. (233.4 m.), on lake Temiskaming. The rock-cuts and cliffs along the way show exposures of conglomerate and greywacké of the Cobalt series, and also of the Nipissing diabase.

THE PORCUPINE AREA

BY

A. G. Burrows.

CONTENTS.

INTRODUCTION.

The Porcupine gold area, which for the past four years has attracted much attention, is situated on the Hudson Bay slope of northern Ontario. The latitude of Niven's First Base Line of 1899, which runs through the centre, forming the south boundary of Tisdale and Whitney, is 48° 27′ 54″; consequently the area is somewhat farther south than the Canada-United States boundary in Manitoba and other western provinces. The camp is in the Temiskaming judicial district. Lying along the southern fringe of the great clay belt of Northern Ontario, it adjoins a prospective farming country. In this belt many townships have been laid out in six or nine-mile squares and subdivided into concessions and lots; in the gold area itself and in the adjoining country to the north, many half lots containing 160 acres each have been granted to veterans as homesteads.

During the last two years there has been little extension of the gold-bearing area beyond what was known in 1910. The discoveries of Hollinger and Wilson of 1909, now the Hollinger and Dome mines respectively, still remain the most important that have been made, while Tisdale is by far the most important township.

Ingress to the Area.

A branch line of the Temiskaming and Northern Ontario railway has been constructed from Iroquois Falls (on the main line), in a southwesterly direction to the town of Timmins, a distance of 33½ miles.* Timmins by railway is 485 miles distant from Toronto.

A number of townsites have been established in the area. The most important of these are: Porcupine, South Porcupine and Lakeview, situated on Porcupine lake; Schumacher, on Pearl lake; Timmins, west of Miller lake; and Mattagami, on the Mattagami river.

Elevation of the Area.

In elevation the area averages about 1,000 feet† above mean sea level. In this respect it is similar to Cobalt, which

* 0.621 mile = 1 kilometre. † 3.28 feet = 1 metre.

Street in South Porcupine, March, 1912.

lies 100 miles to the southeast, south of the height of land. The divide between the Hudson Bay and the St. Lawrence waters is not pronounced, being only about 1,300 feet above sea level.

The highest elevation near Porcupine is along the south boundary of Jamieson, where a felsitic ridge has an altitude of 1,350 feet above sea level.

The country from Night Hawk lake to the Mattagami river is one of low relief. Occasional ranges of hills reach an elevation of 150 feet, but generally abrupt changes in elevation are less than 50 feet. Often in a low area rocks outcrop only a few feet above the surrounding drift and are only a fraction of an acre in extent. Northwest, south, southwest and southeast of Porcupine lake the country is somewhat elevated, and rock exposures are more frequent than in most of the area.

The First Prospecting.

Previous to the building of the Temiskaming and Northern Ontario railway, the area was difficult of access and little prospecting was done in it until 1909.

In 1906 some work was done by prospectors on a vein near Miller lake and a few hundred feet from the present Hollinger vein. Evidently seeing no gold, and having no assays made, they abandoned the property. In the same year claims were staked in Shaw township on what is described in the application as a "vein of sugar quartz and hematite iron." This is of interest since the so-called vein is simply the upturned edges of the Keewatin iron-formation.

In 1908 claims were staked by Mr. H. F. Hunter on the east shore of Porcupine lake in Keewatin formation. Gold was found disseminated through quartz and schist in a sheared zone.

It was not, however, until the following year that the spectacular discoveries of J. S. Wilson, on what is now the Dome property, caused a rush to the district, and in a few weeks practically all of Tisdale and a great part of the adjoining townships and unsurveyed territory were staked out in mining claims.

Superficial Deposits.

The area is for a considerable part drift-covered. These drift deposits consist largely of stratified clays, sands and gravels of post-Glacial age; and in addition there are patches of morainic material. Sections of stratified clay, overlain by sand, are well exposed on the Mattagami river, north of Pigeon rapids, and along the shores of Night Hawk lake. Most of the islands in this lake have a rocky shore line, but are capped by stratified material. Where the soil has been removed the rocks are seen to have been intensely glaciated. The fine-grained greenstones have well preserved the scratches and grooves produced by glaciation. On several islands were noted two sets of striations, S. 15° W. mag., and S. mag., the latter representing the later ice movement. Owing to the lack of drainage, much of the country, though higher than the rivers and lakes, is very wet, but would be suitable for agricultural purposes if properly drained. For a description of the agricultural possibilities of the country the reader is referred to reports by Mr. A. Henderson.*

Forest Fires.

During the past two years forest fires have greatly ravaged the area around Porcupine. About the middle of May, 1911, a fire completely destroyed the surface workings and buildings of the Hollinger mine. From that time forest fires were burning in the area until the middle of July. On July 2nd, the buildings of the Dome Extension and part of the townsite of Pottsville were destroyed.

The greatest fire of the year occurred on July 11th, when, after a prolonged dry season, a hurricane from the southwest brought up a fire which did the greatest damage. The surface workings and buildings of the Dome, West Dome, Vipond, Standard, Preston East Dome, North Dome and several other properties were entirely destroyed. The town of South Porcupine was completely wiped out, and almost all that part of Pottsville which escaped the fire of July 2nd. The north part of Porcupine (Golden City) was also destroyed. This

* Agricultural Resources of Abitibi, Bur. M'n., Vol. XIV. (1905); *Idem* Vol. XV. (1906).

Stratified clay at Sandy Falls, Porcupine area.

fire was attended by a great loss of human life, 71 in all having lost their lives either by being burned, suffocated or drowned.

Timber.

In the parts which have escaped the fires there is a dense growth of timber, including white and black spruce, jackpine, birch and poplar. It is interesting to note that a growth of young tamarac is replacing the old tamarac trees, which have all been destroyed in recent years by the larch saw-fly.

GEOLOGY.

The compact rocks of the area may all be referred to the pre-Cambrian, and are similar to those of the Cobalt area, described on preceding pages. However, only the Keewatin and Temiskaming series are of importance in the part of the area that is productive at present. The following table shows the age relations.

Pleistocene.

Post-Glacial.—Stratified clay, sand, and peat.
Glacial.—Boulder clay.

Pre-Cambrian.

Later Intrusives.—Quartz-diabase, olivine-diabase, etc.

Igneous contact.

Cobalt Series.—Conglomerate.

Unconformity.

Temiskaming Series.—Conglomerate, quartzite, greywacké, slate or delicately banded greywacké.

Unconformity.

Laurentian.—A complex of granites older than the Cobalt series. It intrudes the Keewatin, but its relationship to the Temiskaming is not definitely known; it may be in part older and in part younger than the Temiskaming series.

Igneous contact.

Keewatin.—The series consists chiefly of basic to acid volcanics, much decomposed, and generally schistose; amygdaloidal basalts, serpentine, diabase, quartz or feldspar porphyry, felsite, iron-formation and rusty weathering carbonates, and other rocks have been recognized.

Keewatin.

The Keewatin has a much greater distribution in the Porcupine area than the other members of the pre-Cambrian, and it is also of more importance economically, since it contains the greater number of the gold-bearing veins which have so far been discovered.

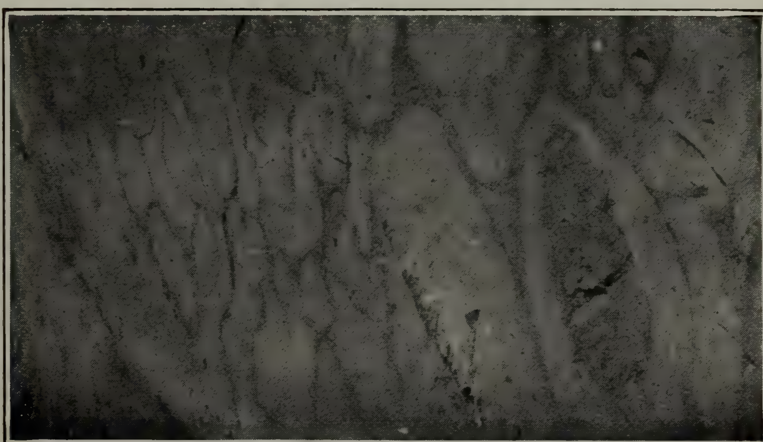
As in other parts of Ontario, the series is highly metamorphosed, and many rocks are so much altered as to give little evidence of their original character. However, much of the series can be seen to consist of basic and acid volcanics such as basalts and porphyries, with intermediate types, although these are often altered to schists. Where schistose, the general strike over a considerable area is found to vary from east and west to northeast and southwest, while the dip is generally steep to the north.

Basic Rocks. Among the more massive rocks are greenstones (basalts, etc.), which frequently show a striking ellipsoidal or pillow structure. Amygdules often accompany this structure and occur most abundantly along the rims of the ellipses. The centres of the ellipses are often bleached to a light greenish or whitish color, whereas the margins are considerably darker. This structure is frequently seen in the northwest part of Whitney township. It is very pronounced in the greenstone along the shores of Night Hawk lake and on the islands in this lake. On the main land, opposite Callinan's island in Night Hawk lake, the ellipsoidal greenstone has been rendered quite schistose, so that the structure appears as alternate light and dark bands. Some of the greenstones have been brecciated and resemble conglomerate.

Serpentine occurs in parts of the area in large volume. The range of hills immediately southeast of Porcupine lake are largely composed of this rock, which is impregnated with much carbonate. Occasional veinlets of fibrous asbestos are seen. A section of a sample of serpentine rock from

the southeast shore of Porcupine lake is made up largely of fibrous serpentine, together with residual iron oxides which in arrangement suggest original crystals like olivine. The remainder of the rock is dolomite. A chemical test showed the absence of chromium oxide in this rock.

A spotted rock, from the northeast part of the West Dome in lot 5 in the first concession of Tisdale, is probably an altered amygdaloidal lava. The schistose matrix consists of secondary material, dolomite, sericite, etc., and the amygdules, whose margins are stained with limonite, are filled with calcite, sericite, and quartz. Some of the amygdules are an inch in length.



Ellipsoidal, Keewatin, greenstone, Night Hawk lake.

An amygdaloidal rock from the 100-foot level of the Vipond mine is entirely decomposed. The amygdules are now stained with red iron oxide and show much clear calcite. Rims of chlorite surround the amygdules, along which are scattered grains of magnetite. There are also some minute grains of a secondary mineral, quartz or feldspar.

A sample from the main shaft at the Dome Extension is quite schistose in thin section. Rods of plagioclase can still be recognized, while the ferro-magnesian mineral is entirely altered to chlorite. Quartz is present in small

grains, and calcite is abundant. Secondary feldspar is present in the form of clear grains. The rock may have been a diabase or basalt, but is now much altered.

Acidic Rocks. The light-colored, more massive rocks are principally quartz-porphyries and felsite, which in places intrude the more basic rocks. When the porphyry occurs in some volume, as around the Hollinger mine, the name rhyolite has been applied to it. Much of the porphyry has been altered to a sericitic schist, and frequently a rather massive rock can be traced into a very schistose one. This change can be well seen in the porphyry to the southwest of the Dome mine workings. A porphyry from the south half of lot 4 in the first concession of Tisdale, examined in thin section, shows the phenocrysts to be largely plagioclase feldspar, while quartz in rounded grains is also present. The groundmass is made up principally of plagioclase feldspar and quartz. Laths of tourmaline are scattered through the rock.

The schist at the surface, and at 50 feet in No. 1 shaft of the Hollinger mine, is fine in grain and of a light grey color when fresh. The groundmass consists essentially of sericite (or talc), dolomite, quartz and feldspar. In this occur round and irregular eyes of quartz which may represent phenocrysts in the original rhyolite or quartz-porphyry from which the schist has probably been derived. Cubes of iron pyrites are commonly set in the rock. Other thin sections from the grey schists on the Timmins properties have about the same group of minerals, and most of them effervesce with hydrochloric acid.

The somewhat massive rhyolite exposed just southeast of Miller lake is made up of a fine-grained matrix of quartz, feldspar and sericite, in which are set small phenocrysts of quartz and feldspar. The rock is much impregnated with dolomite.

A sample of schistose rock from the 140-foot level of the Bewick-Moreing shaft, east of Pearl lake, shows an abundance of sericite, chlorite and calcite, with numerous quartz grains. The rock is entirely altered, but some of the quartz grains may be remnants of phenocrysts.

A sample of schistose quartz-porphyry from south of the Dome mine workings shows phenocrysts of quartz and feldspar in a fine-grained groundmass of these minerals.

Narrow quartz veins in Keewatin carbonate schist at Dome property, Nov., 1910.

The extinction angle of some of the feldspar phenocrysts is near that of oligoclase-albite. Sericite scales are often grouped around the crushed feldspar crystals and have penetrated them. Cubes of iron pyrites are abundant.

In addition to the quartz-porphyry there are numerous dikes of a grey feldspar-porphyry. These are generally less than 100 feet in width, and south of Porcupine lake on the Edwards claim intrude the schistose quartz-porphyry. One such dike of feldspar-porphyry, on H. R. 1,043 in Deloro townhip, has been prospected for gold. The dike is intersected with minute stringers of quartz in which most of the gold occurs. A thin section of the rock shows the phenocrysts to be an acid plagioclase which is fairly fresh, but is partly invaded by scales of sericite. Plagioclase is also prominent in the groundmass.

At times the Keewatin has been much crushed and broken, so that the rock has the appearance of a conglomerate; so much so that in the vicinity of the Dome mine, where greywacké and conglomerate occur, it is impossible to draw a close line of distinction between the autoclastic rock and the true conglomerate.

Iron-Formation. Banded iron-formation, grouped with the Keewatin, has an extensive development in parts of the area. It outcrops frequently in the southwest part of Whitney township, in the first and second concessions. The disturbance in the formation here has not been so great as in other areas. Often the bands are lying almost horizontally. In places they have been somewhat brecciated, but are otherwise little disturbed. The bands are alternate reddish or greyish sugary quartz and magnetite or hematite. Sometimes the narrow bands of magnetite, one-eighth inch thick, carry a merchantable percentage of iron, but these are relatively subordinate in comparison with the main mass of rock. It is unlikely that merchantable iron ore will be found in quantity. In parts of the formation iron pyrites replaces the magnetite. Almost horizontal, interbanded iron pyrites and silica are seen on the south half of lot 5 in the second concession of Whitney. A sample of banded quartz and iron pyrites gave 40 cents in gold per ton. Iron pyrites occurs in considerable quantity with a sugary quartz on lot 9 in the second concession, and might be worthy of investigation as a source of sulphur.

Carbonate Rocks. In various parts of the area, associated with Keewatin rocks, are carbonates to which various terms have been applied, such as dolomite, ferro-dolomite, ferruginous carbonate and ankerite.

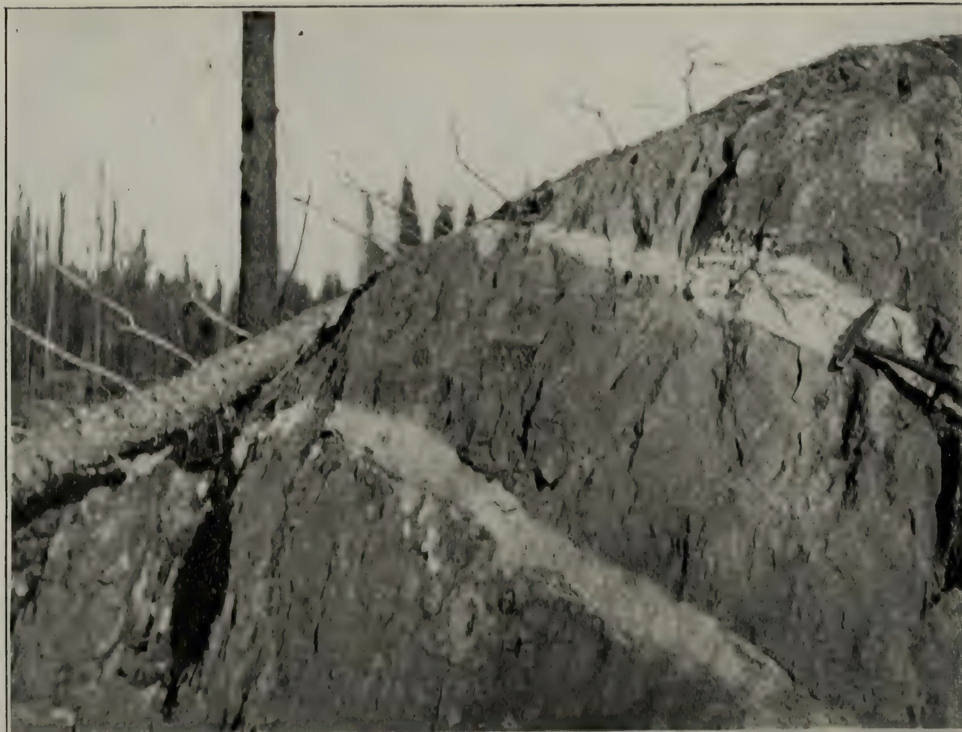
There is much uncertainty as to the origin of this rusty carbonate rock in different parts of the area. The carbonate may occur in at least four different forms, namely, as original bedded material, as a replacement, as vein filling, and as a decomposition product of basic, igneous or other rocks.

That there has been considerable migration of carbonate solutions is shown by the manner in which almost all the rocks of this area are more or less impregnated with it. Sections of quartz-porphyry schist show the presence of much calcite as a secondary mineral. Veins and veinlets of ankerite occur frequently, not only in basic rocks, but in the quartz-porphyry.

Laurentian.

A few outcrops of granite occur in the township of Whitney. This granite is a medium-grained biotite variety, and not typical of that occurring in large volume to the north and south of the area. In south Whitney it intrudes light-colored porphyry of Keewatin age, but its relation to the Temiskaming is not known.

While typical granites do not outcrop in the immediate vicinity of Porcupine, they occur in large volume to the north, west and south of the area, and are known to intrude the Keewatin. Where the granites are exposed over large areas they are medium to coarse in grain, and have been exposed at depth by extensive erosion. It is considered that some of the granophyre, porphyry and felsite rocks are dike representatives of the granites, which very likely underlie the Keewatin and Temiskaming formations at Porcupine. The predominant feldspar of the acid dikes is a plagioclase (near albite), which is also prominent in many of the granites.



Narrow quartz veins (auriferous) cutting conglomerate at Three Nations Mining Co.'s property. Sept., 1911.

The Temiskaming Series.

This series of rocks has been described in preceding pages in connection with the Cobalt area.

At Porcupine the series is of much greater economic interest than at Cobalt, since important gold deposits have been found in it.

The largest area of these rocks at Porcupine stretches from the Dome mine in a northeast direction for about ten miles. It consists of slate, quartzite and conglomerate which have generally been greatly disturbed. The beds have been highly tilted, dipping at angles of 70° to vertical. A secondary cleavage has frequently been developed, and the rocks have been rendered quite schistose. The general direction of the strike is from N.E.-S.W. to E.-W. In this respect the series is related to the Keewatin which has a corresponding strike. It is evident that much of the deformation of the Keewatin was post-Temiskaming.

The sediments at the Dome have been greatly altered to schists. Similar rocks around Three Nations lake have been less altered, and, except for a high dip, greatly resemble the Cobalt series.

The succession of Temiskaming strata is well shown at the property of the Three Nations Mining Company on lot 5 in the fifth concession of Whitney. Along the line between the fifth and sixth concessions very much altered Keewatin rocks, now largely serpentine and rusty carbonate, are exposed. The contact with the Temiskaming conglomerate practically follows this line. Here, at the base of the conglomerate, are numerous fragments of rusty-weathering Keewatin rocks; while farther to the south there are numerous pebbles of acid rocks, including quartz-porphyry, felsite, etc. The conglomerate is overlain by a narrow band of fine-grained black slate, which splits in very thin layers. Overlying the slate is a greywacké which becomes coarser towards the south. About half a mile south of the concession line the rock is quite coarse-grained, and may be called an arkose-like quartzite. Throughout the Temiskaming series there is considerable carbonate, and many samples effervesce briskly with acid.

It should be noted that no granite pebbles were found in the conglomerate. It is believed that the series was laid

down when the surface rocks were largely volcanics, and that the intrusion of at least part of the granite came after the deposition of the Temiskaming, but prior to the Cobalt series.

At the North Dome there is a strikingly banded rock which was originally a succession of fine clay and rather coarse sand layers. A secondary cleavage is developed at a low angle with the upturned edges of the strata.

On the Foley-O'Brian the sediments in addition to being highly tilted show a wavy structure along the strike.

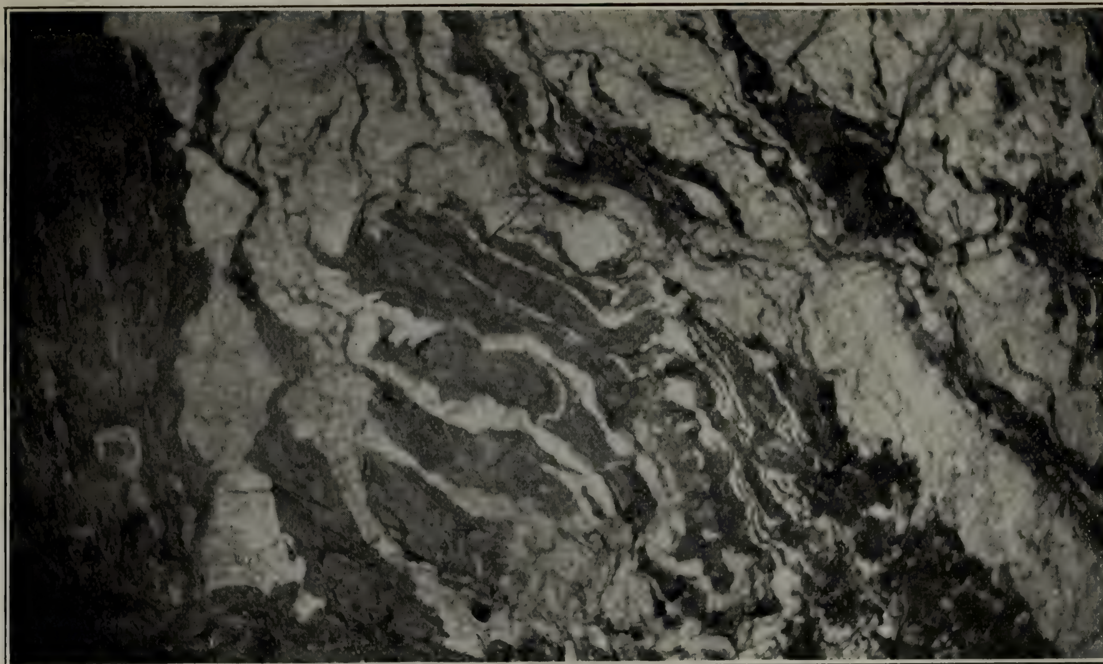
At the Dome property, in contact with large quartz masses, is a conglomerate which is likely basal. On the weathered surface the included fragments of porphyry, greenstone, schist, etc., are conspicuous, but in freshly broken pieces the conglomeratic character is easily overlooked, since the rock breaks in prismatic blocks resembling schist. The included pebbles are frequently drawn out in the direction of the schistosity.

The Cobalt Series.

The younger series of pre-Cambrian sediments has been observed only in small volume on the south boundary of Langmuir township, about 15 miles to the southeast of Porcupine lake.

Later Intrusives.

In all parts of the area are basic dikes which generally are less than 100 feet in width. These dikes appear to here represent the Nipissing diabase of Cobalt and the later intrusives of that area. At Porcupine they are believed to be much younger than the gold deposits.



Contact of quartz and schist on the N. W. wall of No. 4 vein, Hollinger mine, where vein was intersected in the first cross-cut from No. 1 vein on the 100-foot level. Width of exposure, 6 feet.

THE GOLD DEPOSITS.

Origin.

It has been suggested, in the notes accompanying the editions of the Porcupine map, that the quartz veins of the area are the result of a granitic intrusion, the immense quantity of quartz present in the veins having been supplied by the acid magma as a differentiation product. The primary quartz of the veins shows evidence of having been deposited under pressure, as it contains numerous cavities of gas and liquid inclusions. The quartz has filled the fissures rapidly, as there is generally an absence of well-defined walls, except where there has been secondary movements. Quartz and rock are often cemented, forming a contact like that of an intrusive.

Mr. C. W. Knight noted the occurence of feldspar in a quartz vein on the Miller-Middleton, one of the Timmins locations, and suggested the relationship of the deposit to granite or pegmatite dikes. The feldspar which is an acid plagioclase has also been noted in other veins, including the No. 1 vein of the Hollinger, the Rea vein, and in many of the narrow veins in the vicinity of Three Nations lake. The feldspar is most abundant near the margins of the veins. The extinction angle of the feldspar in the veins on the Three Nations Lake Mining Company's claim shows it to be very near albite. A chemical analysis of this feldspar gave: Soda, 10.37 per cent.; potash, 0.90 per cent.

The mineral scheelite, calcium tungstate, occurs in some of the veins around Pearl lake as one of the earliest constituents. It has been found in the Jupiter, Plenaurum, McIntyre and Hollinger, but only in very minor quantity. It is interesting to note that scheelite generally occurs with minerals like topaz, cassiterite, tourmaline, and arsenopyrite in pegmatitic veins, which are considered to have a genetic relationship with granites. The presence of scheelite in the Porcupine veins may point to the pegmatitic origin of the veins in this area.

Tourmaline occurs quite frequently, not only as a later mineral in the veins but with the original quartz, as at the Dome Extension, West Dome and other properties.

Arsenical pyrites is abundant in the quartz veinlets on the McAuley-Brydges claim in Bristol township.

Quartz masses in contact with schistose-conglomerate, Dome mine, Nov., 1910.

The following sulphides have been recognized in veins at Porcupine: iron pyrites, copper pyrites, pyrrhotite, arsenical pyrites, galena and zinc blende. Of these the most abundant is iron pyrites, which occurs in some quantity in all the gold-bearing veins. Copper pyrites, galena and zinc blende, although also widely distributed, occur in minor quantity. Pyrrhotite is the chief sulphide in the veins which are being developed in No. 4 shaft of the Dome Extension.

Only one telluride has been recognized, occurring in the quartz-carbonate deposit at the Powell claim, M.E. 20, in Deloro township. A chemical analysis of the mineral gave the following results, silver 61.88 per cent, gold 0.10 per cent., with strong reactions for tellurium, indicating the mineral hessite. Native gold occurs as a later constituent in minute seams in the hessite.

In support of the theory of the relation of the quartz veins of Porcupine to granite intrusions, may be mentioned the following:

1. The irregular occurrence of the quartz in many of the deposits, in lenticular masses, resembling pegmatite dikes.

2. The occurrence of feldspar, scheelite, and tourmaline in the quartz in several deposits.

3. The great pressure at which the quartz has been deposited, indicated by the presence of liquid inclusions and gas bubbles. These are frequently seen in quartz in granites.

4. The frozen contacts of quartz and enclosing country rock. The free walls seen at some properties indicate a secondary movement in the quartz, since these walls are slickensided. Where free walls exist they may be either the hanging or foot wall, while the other wall is indistinct—grading into the country rock.

5. The occurrence of narrow felsitic dikes, frequently cut by minute veinlets of quartz, which represent the final solidification of the felsitic magma, and which frequently carry gold values as on Night Hawk lake.

Character of the Gold-Bearing Deposits.

The occurrence of gold at Porcupine is associated with the quartz solutions which circulated through the fissures in the Keewatin and Temiskaming series. The irregular fissuring has produced a great variety of quartz structures,

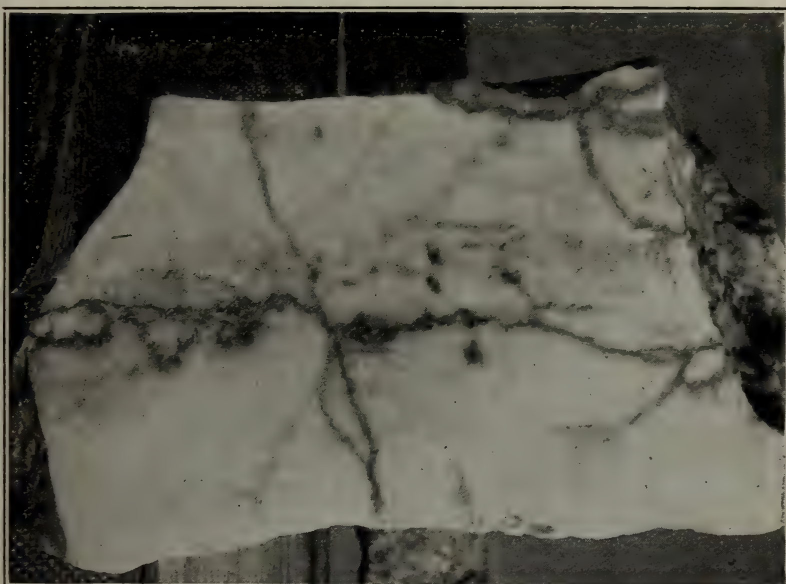
Part of "Golden Stairway" vein containing spectacular gold showings, Dome mine. The lenticular character of the deposit is shown; the rock enclosing quartz is slate, Oct., 1911.

varying from the tabular, though often irregular or lenticular, vein which may be traced several hundred feet, to mere veinlets, often only a fraction of an inch in width and a few feet in length, which ramify through a rock that has been subjected to small irregular fissuring. This latter variety is well illustrated in the fissuring of ankerite bands, so characterictic of some of the gold deposits of Porcupine. Irregular and lenticular bodies of quartz often occur which may have a width of ten or twenty feet, but which die away in a distance of fifty feet. Again, there are dome-like masses of quartz which are elliptical or oval in surface outline. In some parts at least these masses can be seen in contact with underlying rocks at a low angle, which would suggest that they are broad lenticular masses which have filled lateral fissures in the country rock. The most conspicuous dome masses are those of the Dome property, where the two largest are about 125 feet by 100 ft. A fissure may be vertical and regular at some points. At others it may incline at a lower angle to the horizontal or take on a more or less lenticular form.

The term "vein" as here used is not confined to the filling of a single fissure with well-defined walls, for this type of vein is rather the exception in the Porcupine area. The fissuring has been so irregular that a "vein" in one part may consist largely of quartz, and in another part of numerous veinlets of quartz and intervening schist, resembling a stockwerk; again, the main part of a vein may be almost vertical in attitude, but many veinlets, branches from the main vein, may extend laterally into the country rock. It is often found that the values are obtained in parts of the vertical vein which have been subjected to a later movement and enrichment, whereas the lateral veins have little or no value. This is illustrated in the No. 1 vein at the Rea mine.

The relationship of the strike of the veins to that of the enclosing rock is often difficult to determine, since generally along the veins there has been shearing of the country rock which may conform to the general direction of the strike of the veins. However, by determining numerous strikes in the schist away from the veins, it is seen that the majority of them are inclined to the strike of the enclosing rocks. In dip the veins vary from vertical to nearly horizontal. In No. 1 shaft of the Hollinger the vein is practically vertical,

while a series of narrow quartz veins, 6 to 18 inches wide on the Lindburg claim, have a dip at the surface of only 20°. The prevailing dip of the schist in the Porcupine area is to the north at a high angle, and frequently the veins dip distinctly to the south across the cleavage of the schist. While it is apparent that most of the deformation of the country antedates the vein formation, nevertheless there is a decided tendency in many cases for the fissuring to be influenced by the direction of schistosity, which is also a direction of



Photograph of quartz from the Swastika mine. The quartz shows dark streaks in crushed areas. Iron pyrites is abundant along the dark lines, together with visible gold. Length of sample, 3½ inches.

weakness; hence we find veins having a more or less lenticular structure, the strike of which closely corresponds to that of the country rock.

Lenticular veins occur chiefly where the country rocks have been intensely sheared or rendered schistose, as around Pearl lake. Usually when there has been less disturbance, the veins are more likely to have a marked difference in strike from the enclosing rock—as around Three Nations lake and the porphyry area south of Simpson lake. It may

be stated that the larger and usually lenticular veins of the area occur where the rocks are extremely schistose, while the narrower, better defined veins occur as stringers from these main lenticular veins, or in less disturbed areas.

Distribution of Veins.

While gold-bearing veins occur over a wide area and are often isolated, it is seen, from a number of those already discovered, that they occur in groups along certain lines. For instance, in Tisdale township there are at least three distinct areas where the fissuring has been most pronounced. One such area extends from the southeast end of Miller lake, on lot 11, in the second concession, in a northeasterly direction for three miles, and includes such veins as the McEnaney, Miller-Middleton, Hollinger, Dixon, McIntyre, Jupiter, Rea, and others with visible gold. The average strike of the veins here is northeast and southwest. An exception is a vein on the McEnaney, which strikes northwest and southeast.

Another series, including the Smith, Davidson, Crown Chartered and Dobie, occurs in the northeast part of the township. To these should be added the Scottish-Ontario, Mullholland, Hughes and Gold Reef, which are in the northwest part of Whitney township. The general direction of these veins is east and west.

Again, in the southeast part of the township is a group including the Dome Lake, West Dome, Dome, and Dome Extension, with a general strike north of east.

Similar groupings occur in other parts of the area in which gold-bearing veins have been found.

Occurrence of the Gold.

A field examination shows that there is an irregular distribution of the gold in the quartz veins. Very often it occurs along dark streaks in the quartz, along the contacts of quartz and schist, or around patches of dark colored mineral in the quartz. At the surface, rich portions of veins are often indicated by rusty streaks or patches, while at depth the rusty character gives place to dark grey, black or greenish colors.

GOLD ORE.

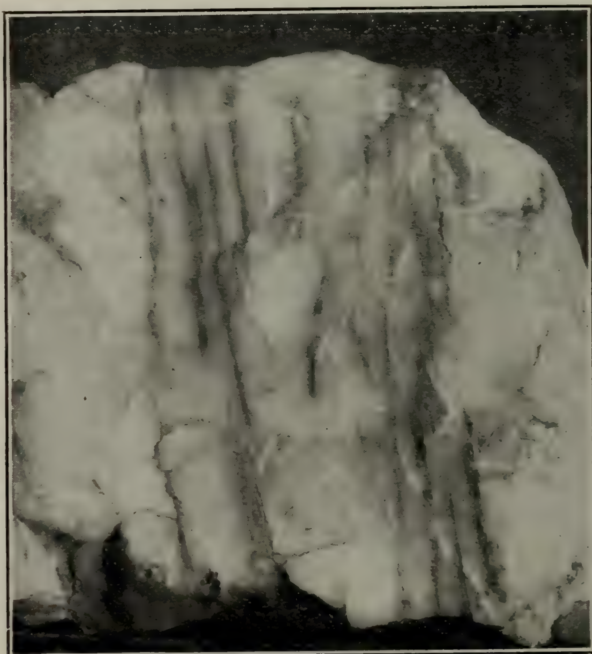
1. Microphotograph, McEnaney.   2. Microphotograph, Vipond.

1. Fine grained carbonate, tourmaline, quartz, feldspar, and sericite.
2. Brecciated quartz with later corbonate.

MICROSCOPICAL AND OTHER CHARACTERISTICS.

Under the microscope the gold is generally found in areas which have been greatly crushed or in the quartz or schist bordering on these areas.

The prominent minerals which occur in the crushed areas are pyrite, calcite, dolomite, sericite, chlorite, tourmaline and quartz. It is thought that most of the gold has

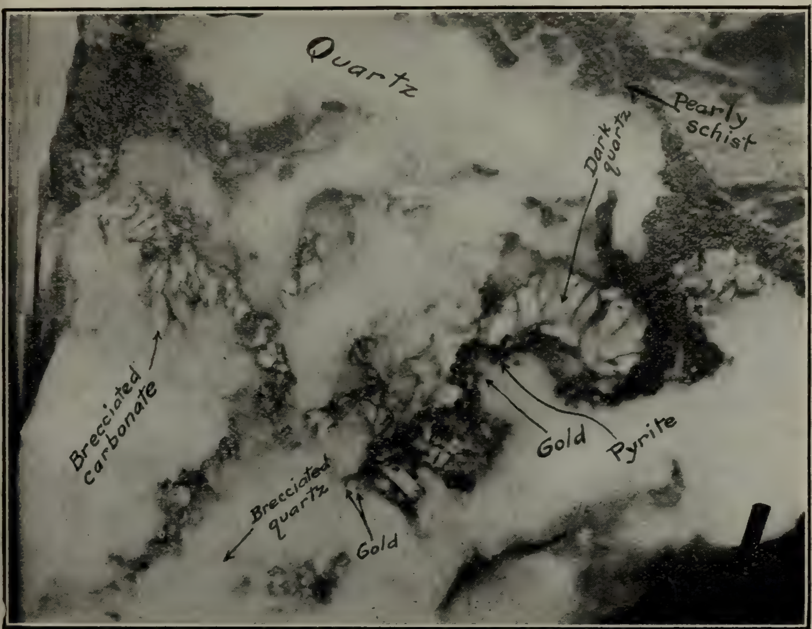


Streaked ore from the Jupiter mine, Porcupine. The dark lines are tourmaline; the quartz is much crushed and contains visible gold.

been deposited along with pyrite from the solutions which circulated in the minute fissures and crushed areas of the primary quartz of the veins. The quartz of No. 1 vein of the Hollinger mine shows numerous dark streaks in parts of it and often across the width of the vein. These are generally short and irregular in distribution. Iron pyrites and often galena occur with the gold. Examined microscopically, the quartz is seen to occur in fairly large grains,

to contain liquid and gas inclusions, and to have been subjected to secondary pressure and granulation along the margins of the grains. The iron pyrites often occurs in well shaped crystals which have been formed subsequently to the crushing.

The fine dark streaks may have resulted from a shrinkage of the quartz, forming filmy cracks which may have become slip or crushing planes along which the richer gold-bearing solutions were deposited at a later period.



Brecciated structure of quartz from McIntyre main vein (natural size).

The minute dark streaks in the quartz are frequently slickensided, and this character may often be seen in hand specimens, as in those from the Rea or Vipond mines.

It should be noted that where cracks or fracture planes have been produced in a quartz vein and subsequently filled by minerals from solution, secondary quartz can be distinguished with difficulty, if at all, from the original quartz. Hence it is not always possible to say whether visible gold in such a vein occurs in the original or in secondary quartz.

Often a vein may show a width of ten feet but the fractured portion may be only a few feet, or even inches, wide along either wall. In this portion there may be many streaks of dark mineral which are often parallel, giving a banded character to the ore, as in many of the veins in the north part of Whitney and Tisdale, namely, at the Mullholland, Scottish Ontario, Davidson and adjoining properties. A similar banded structure is seen at the Rea mine. At these properties tourmaline is the principal mineral of the streaks. The gold may occur along these lines or in the intervening quartz, which is often much crushed and filled with later minerals.

Several sections were examined, which showed grains of gold apparently enclosed in the primary quartz, but the occurrence is much less prominent than where gold occurs in the crushed areas.

It is important to note that practically all the veins which are gold-bearing contain considerable carbonate of varied composition. Wherever the enclosing rocks are schistose they always carry carbonate and frequently effervesce with cold hydrochloric acid. Much of the carbonate of the veins has been absorbed from the wall rock, while portions have been formed from ascending solutions which circulated through the veins. Pyrite and grains of gold frequently occur in the carbonate.

Carbonate in the form of ankerite constitutes the main portion of veins at the West Dome, Apex, and in parts of Deloro township. This carbonate is distinctly earlier than the quartz veinlets which intersect the ankerite veins. Both the ankerite and quartz have been fractured and veinlets of later carbonate deposited in them.

Since the whole surface of the area has been deeply eroded and glaciated, there is now little evidence of secondary enrichment. The enrichment is very superficial, extending only from a few inches to a few feet in depth. The outcrops of the veins and wall rocks are usually discolored or decomposed, due to the oxidation of the iron pyrites and the ferrous carbonate in the ankerite or other iron-bearing carbonates. Cubes of iron pyrites are occasionally obtained at the surface, while copper pyrites and arsenopyrite also occur near the surface. Where the veins have been oxidized to any depth, there are generally

Quartz vein on 100-foot level, McEnaney mine. The dark spots are drill holes.

some very recent water courses in evidence. Developments so far have shown that, after this very superficial zone has been penetrated, the character of the vein material has remained the same as far as mining operations have continued.

MINING AND MILLING.

Detailed descriptions of the mining and milling operations in the Porcupine area are given in the Annual Report of the Ontario Bureau of Mines, and in Mr. A. A. Cole's Annual Report to the Temiskaming and Northern Ontario Railway Commission.

TEMAGAMI

BY

WILLET G. MILLER.

Lake Temagami, with its numerous islands and bays and its shores covered with evergreen timber, is one of the most beautiful sheets of water in North America. It is situated in the Government Forest Reserve, and since the completion of the Temiskaming and Northern Ontario Railway, the lake has become very popular with tourists and sportsmen. Fish and game are abundant in the vicinity of Temagami and the numerous adjacent lakes and streams. The locality is especially noted for moose and for bass and trout fishing.

Near Temagami station there are exposures of the Keewatin and Cobalt series. Within a half mile northward of the station an iron range of interbanded magnetite and jasper, which has a width of several hundred feet, is to be seen. Two or three miles northward there are deposits of mispickel, pyrrhotite, and copper pyrites. The last-named mineral is also found near the lake.

Good contacts of the Cobalt series with the Keewatin are exposed along the railway a short distance north of the station.

The schistose rocks of the Keewatin may be divided into the paler-colored and more acid varieties, which are deformed quartz porphyries or porphyrites, and the more deeply colored or basic schists resulting from the shearing of hornblende porphyrites, basalts and diabases. The extreme deformation of the more acid types produces sericite schists, which reveal little or no trace of their original structure.*

The iron-formation (jaspilyte) is similar to that of the well known Vermilion range of Minnesota. It is infolded with the Keewatin schists, all dipping at high angles.

The iron-formation, in places 1,000 feet in width, probably represents chemical sediments that were deposited on the surface of the Keewatin volcanic rocks. At the base of the iron-formation, there is frequently a comparatively thin layer of fine-grained greywacké.

Frequently the interbanded material of the iron-formation contains 35 to 40 per cent. of metallic iron. By magnetic concentration, judging from experiments that have been performed, a merchantable ore can be produced.

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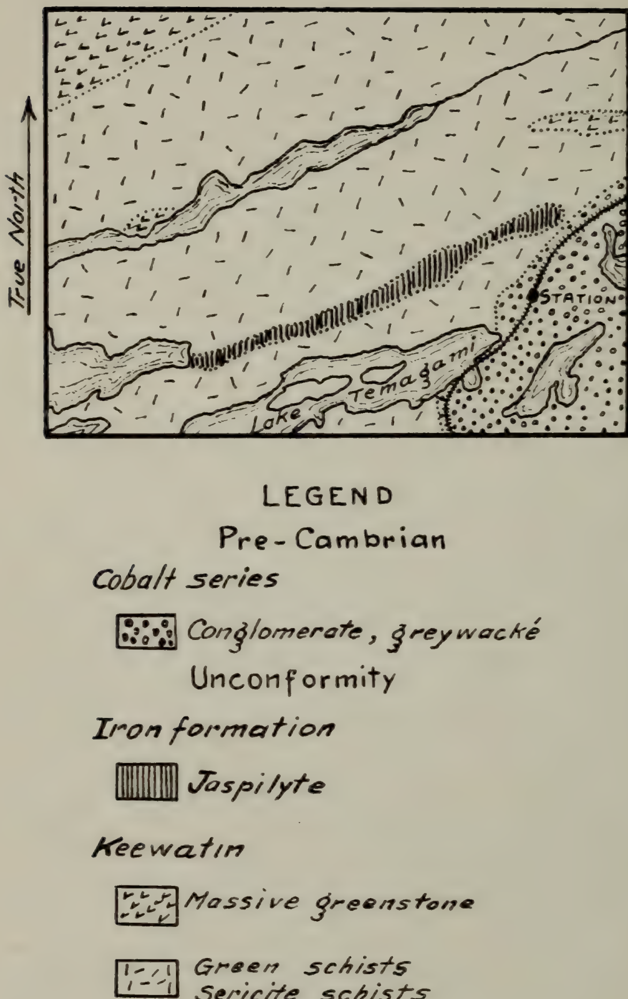
*Geol. Sur. Canada, Vol. XV., 1902-3, p. 128A et seq. Map No. 944.



Geological map of area near Temagami railway station, scale 1 mile to 1 inch.

(From map No. 944, Geological Survey of Canada.)

ANNOTATED GUIDE.

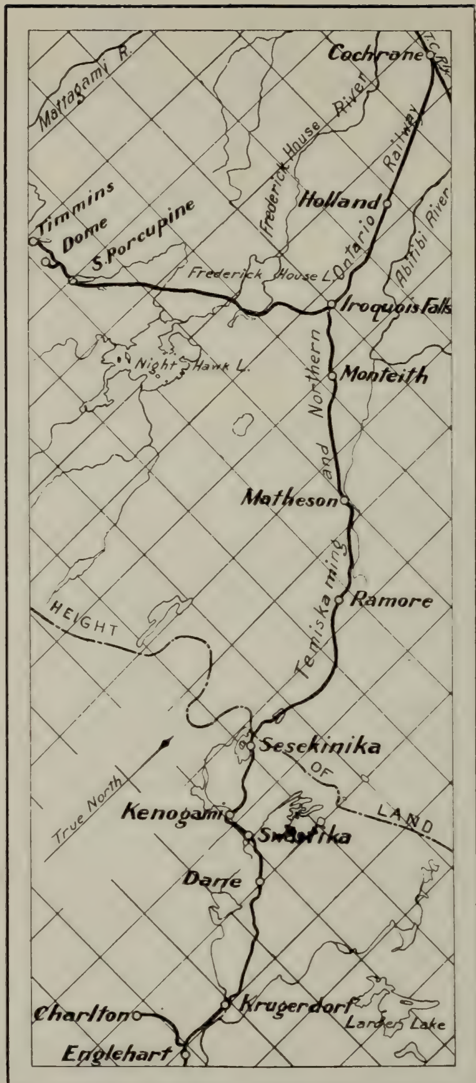
HAILEYBURY TO SWASTIKA, IROQUOIS FALLS JUNCTION AND PORCUPINE.

Miles and
Kilometres.

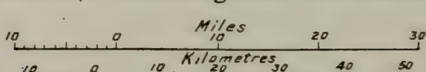
107.44 m.
173 km. Altitude 766 ft. (233 m.). The town of Haileybury has a splendid location on the easterly slope of a clay ridge, over-looking Lake Temiskaming, an expansion of the Ottawa river which here forms the boundary between the Provinces of Ontario and Quebec. From the railway station to the lake there is a descent of 175 ft. (53.2 m.). The clay, which is finely stratified, is utilized in the manufacture of red brick at Haileybury and New Liskeard.

One-half mile west of the station is an exposure of Silurian limestone (Niagara) which is prolific in fossils. This limestone has been burned for lime, and is also used for road material and building stone. It lies nearly horizontally, and is the youngest compact rock in the area.

112.64 m.
181.2 km. Altitude 642 ft. (195.6 m.). Leaving Haileybury there is a descent to New Liskeard, which is situated in a valley on Wabi bay. Between the towns are several cuttings on the railway which show the beautifully banded character of the clay. Good exposures of the Temiskaming series are to be seen along the lake shore. Niagara limestone can also be observed in the ridge directly west of the New Liskeard station. New Liskeard lies almost on the southerly boundary of a farming country, which stretches 35 miles along the railway to Krugerdorf station. This area is entirely drift-covered, while the Pleistocene deposits consist of stratified clay, sand and gravel, considered to have been laid down in lake Ojibway, the last of the glacial lakes. Here and there recent water courses have cut deep valleys in the Pleistocene deposits, but generallv the country has a rather flat or rolling appearance. The high ridge



Route map between **Englehart** and **Cochrane**



which may be seen to the east of New Liskeard, known as Wabi point, is composed of Niagara limestone. Seven miles northeast of New Liskeard station is the Casey Cobalt silver mine, which is one of the few properties, outside of the main Cobalt silver area, which has shipped high-grade silver ore.

128.59 m. 206.7 km. Altitude 816 ft. (248.6 m.). At Earlton a branch line extends from the main line to the Elk Lake silver area.

138.48 m. 232.7 km. Englehart, altitude 677 ft. (206.2 m.). From this point a short line extends westward to the Charlton farming area A part of this line from mileage one to two and three-quarters has been constructed along the north side of a high, rocky ridge. In the rock cuttings are exposed massive and schistose Keewatin rocks, some of which are greatly altered, showing torsion cracks, filled with calcite and quartz. numerous faults and crushed areas. The Keewatin is intruded in places by diabase dikes. Where schistose, the rocks strike N. 80° E. and dip N. 60°.

146 m. 234.8 km. Altitude 770 ft. (234.6 m.). The first outcropping of rock on the main line occurs at the crossing of the Blanche river, just south of Krugerdorf station. Here the track is 110 feet (33.4 m.) above the rapids which are formed by a barrier of massive, flesh-colored granite.

North of this point rock exposures become more numerous, showing here and there through the stratified clay. These consist of coarse, reddish granite as far as mileage 153. Just south of this mile the acid rock is gneissoid, showing pink and grey bands striking N. 72° W. Glacial striæ are well preserved on the granite showing a direction of S. 10° E. This granite has been used in the construction of the station at Matheson.

North of mileage 153 a Keewatin area is entered. The rocks are largely greenstones, some of which are basalt, showing occasionally

ellipsoidal or pillow structure. At the south end of the first rock cutting north of mileage 153 there is Keewatin iron formation carrying considerable iron pyrites; at one point there is a rusty band eight feet wide carrying streaks of massive iron pyrites. The basic rocks are cut by narrow, reddish, feldspathic dikes which contain much mica. Just south of mileage 154, one of these dikes, two feet in width, shows in a rock cutting on the southwest side of the track. Fifteen chains north of this mileage, a dark mica lamprophyre cuts the greenstone.

Marked ellipsoidal structure is seen at mileage 156 on the northeast side of the track.

159.74 m. 256.7 km. Altitude 1,035 ft. (315.4 m.). At Dane a 17-mile (27.3 km.) wagon road leads to the Larder Lake gold area, where the gold occurs in rusty-weathering carbonate and porphyry rocks which are cut by veinlets of quartz.

At mileage 160½, reddish syenite occurs on the south side of the track. The high range of hills observed to the south are reddish hornblende syenite which intrudes the Keewatin greenstone.

Just east of mileage 162 there is a rock cutting through banded iron formation. The rock is very rusty, and melanterite has been formed from the disseminated iron pyrites. Keewatin greenstone is observed continuously in the cuttings as far as Amikougami creek, east of Swastika. The Lucky Cross mine is to the south of the track, just east of the Amikougami creek, while about half a mile to the southwest is the Swastika mine. Between the last mentioned creek and the Blanche river is a ridge of grey feldspar-porphyry. Along this porphyry ridge a number of mining claims have been staked out, and the chief gold veins occur where the greenstone has been intruded by this rock.

164.7 m. 265. km. Altitude 1,007 ft. (306.9 m.). The town of Swastika is underlain by conglomerate which contains numerous pebbles of porphyry and jasper, while the high ridge southwest of the town is also conglomerate. Numerous narrow dikes of red feldspar-porphyry intrude the conglomerate for two miles beyond Swastika.

Conglomerate and greywacké are shown in the cuttings as far west as Kenogami station.

168.16 m. 270.4 km. Altitude 1,013 ft. (308.8 m.). In the cutting south of Kenogami station, the conglomerate and greywacké have a vertical dip. This conglomerate has been provisionally classed as "Temiskaming." The glacial striæ seen on the polished surfaces near Kenogami strike S. 55° E.

Another Keewatin greenstone area extends north of Kenogami to mileage 178½. At the fourth crossing of the Blanche river there is basalt which is intruded by a dike of porphyritic diabase.

At mileage 169 is a basalt which has been crushed to a friction breccia.

On approaching Sesekinika lake there are several dikes of fresh quartz-diabase. At mileage 172 one of these has a width of 60 feet.

175.56 m. 282.4 km. Altitude 1,022 ft. (311.4 m.). Sesekinika lake contains numerous islands on which Keewatin rocks occur. On account of its picturesqueness this lake has been reserved as a summer resort.

HEIGHT OF LAND.

The divide between the St. Lawrence and Hudson Bay waters is crossed at mileage 177½. At mileage 178½ the Keewatin greenstone is intruded by dikes of hornblende syenite. Numerous large boulders of conglomerate of the Cobalt series are scattered along the right of

Otto lake from Swastika mine.

way south of mileage 179. This conglomerate occurs in place at mileage 179, where the strata of the Cobalt series are almost horizontal, showing a succession in ascending order of slate, quartzite and conglomerate.

Twenty-five chains north of mileage 180 the Cobalt series is exposed, showing in ascending order: slate conglomerate, two feet (0.6 m.) of grey and red slate, 10 feet (3 m.) of coarse boulder conglomerate. Just beyond, opposite the north end of Twin lake, is a bluff of conglomerate and slate, on the west side of the track, which is 140 feet (42.6 m.) high. A splendid view of the pre-Cambrian peneplain can be obtained from this bluff. North of Twin lake Keewatin greenstones again occur, but rock exposures become infrequent.

Ellipsoidal basalt occurs north of mileage 188, and one-half mile southwest of mileage 190 there is a ridge of Keewatin basalt 300 feet (91.4 m.) in elevation.

205.27 m. Altitude 873 ft. (266 m.). (Matheson, the
330.2 km. centre of a farming area, is on the Black river, a branch of the Abitibi river. McDougal's chute is formed by a barrier of later diabase which intrudes basic, schistose Keewatin. The greenstone is also cut by a dike of grey porphyry.)

Eleven miles east of Matheson is the Munro township gold area. Here narrow auriferous quartz veins occur in the Temiskaming greywacké and slate.

218.03 m. Altitude 922 ft. (281 m.). At Monteith is
350.7 km. an Ontario Government experimental farm.

222.03 m. Altitude 897 ft. (273.3 m.). Three and one-
357.2 km. half miles southwest of Kelso is the Alexo nickel mine, a mass of nickeliferous pyrrhotite, at the contact of rhyolite and serpentine. One theory suggests that the ore is the result of replacement in the serpentine, while another suggests a

differentiation from the basic rock. The rocks are older than those of Sudbury, being of Keewatin age.

224.87 m.
361.7 km.
Altitude 945 ft. (288 m.). The Porcupine branch of the Temiskaming and Northern Ontario railway to the Porcupine gold field leaves the main line at Iroquois Falls Junction. This line passes over a drift-covered area for most of the distance to Porcupine lake. Southwest of Iroquois there is much stratified sand and gravel, while approaching Porcupine, stratified clay is observed. Keewatin outcrops at the Porcupine river crossing, and serpentine at mileage 21.

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GUIDE BOOK No. 8

Transcontinental Excursion C 1

Toronto to Victoria and return via Canadian Pacific and Canadian Northern Railways

PART I

ISSUED BY THE GEOLOGICAL SURVEY

OTTAWA
Government Printing Bureau
1913

Gift of
Mary J. Lanier

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TORONTO TO SUDBURY.

Between Toronto and Sudbury the route of Excursion C 1 follows that of A 3, a description of which is contained in Guide Book No. 6. The nickel-copper deposits of Sudbury are described in the same guide book.

SUDBURY TO CARTIER.

BY

A. P. COLEMAN.

ANNOTATED GUIDE.

Miles and Kilometres.

0 m. 0 km. **Sudbury**—Altitude 850 ft. (260 m.). From Sudbury the main line of the Canadian Pacific railway ascends through hills of arkose, quartzite, greenstone and granite to the margin of the nickel-bearing eruptive sheet at Murray mine (Alt. 992 ft.,) (302·3 m.), where the gossan covering the nickel ore of the mine is widespread. The old smelter, now in ruins, stands just to the south of the railway. From this point the line descends toward Azilda, passing for two or three miles (3·2 or 4·8 km.) over gray norite, the nickel-bearing rock, which insensibly passes into flesh-colored micro-pegmatite ending on a hill a little to the west of Azilda. Whitewater lake may be seen to the south.

7 m. 11 km. **Azilda**—Altitude 881 ft. (268·5 m.). From Azilda the route leads westward for 14 miles (12·5 km.) through a flat plain of stratified clay formed in old Lake Algonquin. Above the plain rise a few dome shaped hills of gray Upper Huronian sandstone at Chelmsford and Larchwood. The railway crosses Vermilion river at the latter point.

21 m. 33·7 km. **Larchwood**—Altitude 868 ft. (264·5 m.). From Larchwood westward the road begins to ascend once more over delta sands and

Miles and Kilometres.

gravels of the ancient lake to Phelan, where the railway follows up Onaping river through rough hills of Upper Huronian tuff and conglomerate to the micropegmatite on the northwestern side of the nickel basin. For four miles (6·4 km.) the road passes between high hills belonging to the nickel eruptive, and then enters the Laurentian at Windy Lake, which lies to the south.

32 m. 51·4 km. **Windy Lake**—Altitude 1,221 ft. (372 m.). Beyond this to Cartier the landscape consists of hills of granite and gneiss, partially covered with sand and gravel deposits of Lake Algonquin.

CARTIER TO COLDWELL.

BY

A. L. Parsons.

INTRODUCTION.

The region traversed by the Canadian Pacific railway from Cartier to the boundary between Ontario and Manitoba is underlain by Pre-Cambrian rocks of Laurentian, Keewatin, Lower Huronian, Animikie (Upper Huronian) and Keweenawan age. These solid rocks are very thinly covered by Pleistocene glacial deposits and stratified sands, gravels and clays. Their uneven surface contains unnumbered lakes and numerous rivers, which constitute the principal avenues of communication with the region at a distance from the railway. Along the north shore of Lake Superior the country has a different aspect, where the Animikie and Keweenawan are present. Most of the region is covered with a thick growth of forest.

ANNOTATED GUIDE.

Miles and Kilometres.

38 m. 61 km. **Cartier**—Altitude 1,364 ft. (415·7 m.). Leaving Cartier, the first three miles (4·8 km.) is over typical Laurentian granite and gneiss. Near Geneva is a contact with Keewatin, and for about 10 miles (16 km.) most of the rock is of the typical Keewatin traps, in some instances highly altered. This rock again gives place to the Laurentian $12\frac{1}{2}$ miles (20·1 km.) west of Cartier, and with two exceptions the Laurentian continues uninterrupted to Chapleau, the next divisional point. The two Keewatin outcrops visible in this distance are between Roberts and Ramsay.

109 m. 176 km. **Ramsay**—Altitude 1,403 ft. (427·6 m.).

176 m. 283 km. **Chapleau**—Altitude 1,418 ft. (432·2 m.). The rock between Chapleau and White River are mainly Laurentian and exhibit the typical rounded hills formed by glaciation, the valleys between which frequently contain lakes and swamps. Four Keewatin areas are crossed in this interval. The first of these is about two miles wide (3·2 km.) and is first seen $9\frac{1}{2}$ miles (15·3 km.) west of Chapleau. The second and third are probably connected, though on the railroad they are separated by a band of Laurentian about three miles (4·8 km.) wide. These exposures are about equal in width, and the first of them extends from

236 m. 380 km. $42\frac{1}{2}$ miles (68·4 km.) west of Chapleau, the milepost 58, and the third one begins one mile (1·6 km.) west of **Missinaibi** and extends for $11\frac{1}{2}$ miles (18·5 km.). The fourth is a small outcrop one mile (1·6 km.) west of Williams.

307 m. 494 km. **White River**—Altitude 1,230 ft. (374·9 m.). At White River, a divisional point on the railway, yards have been built for feeding and resting cattle in transit.

Miles and Kilometres.

Beyond White River for 20 miles (32·2 km.) is a granitic region, largely covered with sand, beyond which the Keewatin again appears and continues with slight interruptions to Peninsula, where the remarkable series of laurvikite, syenites and nepheline syenites of the Port Coldwell region begin. From this point the scenery changes from the diversified cliffs on the north and the broad expanse of Lake Superior to the south.

382 m. 615 km. **Coldwell**— Several short tunnels cut through buttress-like projections of the rock masses. The nepheline syenite series extends from near Peninsula to Middleton.

THE NEPHELINE AND ALKALI SYENITES OF THE PORT COLDWELL AREA.

BY

A. E. BARLOW.*

INTRODUCTION.

LOCATION AND SIZE OF AREA.

The Port Coldwell area of nepheline and alkali-syenites is situated on the northeast side of Lake Superior, extending from a point on the Canadian Pacific Railway nearly two miles (3·2 km) east of Peninsula station to another point on the same railway a short distance west of Middleton The area underlain by these rocks, including the shore line and offlying islands, is a little over 15 miles (24 km) from east to west. The necessary curves, in following the sinuosities of the coast line of the lake, have increased the distance along the railway to about 21 miles (33·7 km). Its northern boundary is believed never to be more than 10 miles (16 km.) from the shore or railway. The total area underlain by these rocks is probably about 100 square miles (259 sq. km.)

* Synopsis of paper by H. L. Kerr, Toronto, Canada.

History of Investigation.

The presence of nepheline in the vicinity of Port Coldwell was known very early in the geological investigation of Canada, and some details respecting its mode of occurrence are included in the Report of Progress of the Geological Survey of Canada for 1846-47 (**1**), as also in the Geology of Canada 1863 (**2**). Attention was directed to these early descriptions through the discovery in 1898 by Dr. A. P. Coleman of the University of Toronto of a dyke rich in analcite, near Heron Bay, for which rock he proposed the name "heronite". Subsequently it was shown that "heronite ' was really a decomposed tinguaite (**3, 4, 5, 6**).

In 1900 Dr. Frank D. Adams of McGill University, furnished under the title "On the Probable Occurrence of a Large Area of Nepheline-bearing Rocks on the Northeast Coast of Lake Superior" (**7**), a detailed petrographical description of four thin sections prepared from two rock specimens collected from the vicinity of Peninsula harbour by Peter McKellar in 1870 and Dr. Selwyn in 1882. During the summer of 1900, Dr. Coleman again visited Heron bay, but although successful in discovering certain dykes rich in nepheline, he failed to locate any large area of rocks containing this mineral.

In 1901 another examination was made, during which outcrops of nepheline and other closely related alkaline syenites were revealed between Peninsula harbour and Middleton station (**8**) on the Canadian Pacific railway.

In 1902 Dr. T. L. Walker of the University of Toronto spent a few days collecting museum specimens in this neighbourhood. At his suggestion Mr. H. L. Kerr of the same institution undertook a petrographical study of the specimens then collected, as well as of those obtained by Dr. Coleman, with a view of making a more detailed examination of the whole Port Coldwell area (**9**).

During the fall of 1906 and again in 1907, Mr. Kerr spent about ten weeks in all in the field gathering information regarding the extent of country covered by the several varieties of these syenites. Mr. Kerr's examinations and descriptions have evidently been made with great care and in such detail as to make possible a rather complete and satisfactory statement of this interesting complex of igneous rocks.

Topography.

The Port Coldwell region is exceedingly rough and rocky, consisting of high rounded hills scantily covered with soil or drift material, and therefore easy of geological examination. The central part is in general of higher altitude than the remainder, gradually sloping both to the east and west. The highest point is a hill on Pic island which, according to aneroid determination is 850 feet (259 m.) above the lake. In the vicinity of Red Sucker and in the Coldwell peninsula some of the elevations vary from 250 to 700 feet (76 to 213 m) above the lake,* Fires have destroyed most of the forest in the vicinity of the railway.

GEOLOGY OF THE AREA.

General Relationships.

It is impossible as well as unnecessary to describe in detail the mineralogical composition of all the varieties of these syenites, for as usual their extreme and rapid variation in this respect is one of the most noteworthy features of their development. They are all, however, differentiation products of a highly alkaline magma representing one phase of plutonic intrusion. Although for purposes of description they may be considered as divisible into seven groups, it must be understood that no natural line exists between these respective subdivisions.

1. Quartz syenite.
2. Red hornblende syenite.
3. Augite syenite (laurvikite).
4. White syenite.
5. Nepheline syenite.
6. Essexite, olivine gabbro and picrite.
7. Camptonite.

Petrographic Descriptions of Chief Types.

Quartz syenite.—Quartz syenite is perhaps the least important of these groups, for it is a comparatively rare

* The mean water level of Lake Superior (1871-1900) was 601.7 feet (183.38 m.) above mean tide level.

(quartziferous) variety of both the red hornblende syenite and the augite syenite or laurvikite. It is medium grained, of a dark red colour, in places assuming a distinct greenish tinge. It is typically developed in the vicinity of Red Sucker. The feldspar is a cryptoperthitic growth of orthoclase and albite. Green hornblende, often much fractured and decomposed, is the prevailing coloured constituent. Occasionally there is a very little biotite. Quartz occurs in very small amount, both free and graphically intergrown with the feldspar. Magnetite, resulting from the decomposition of the hornblende, is usually abundant. Apatite, fluorite, pyrite, and secondary calcite, the accessory minerals, are sparingly represented.

Red hornblende-syenite.—The red hornblende syenite is perhaps the most important of the subdivisions mentioned for, from the field work so far accomplished, it seems to cover the largest area. The deep red colour of the very abundant feldspar, in contrast with the dark green of the greatly subordinate hornblende, gives the rock a pleasing and conspicuous appearance. It is usually intimately associated with the darker coloured augite syenite, into which it differentiates by insensible gradations. This scarcely perceptible transition is well illustrated by exposures north of Peninsula harbour and along the railway between Coldwell and Middleton. Pegmatitic phases, in comparatively narrow dyke-like forms, intersect the associated rocks and are present in the midst of the parent plutonic mass. The rock is composed mainly of feldspar (orthoclase and microperthite) and hornbelnde. This hornblende, which is a variety closely related to barkevikite with strong pleochroism in colours ranging from light yellowish green to chestnut brown, is always in subordinate amount, especially in coarse-textured varieties. Pyroxene (diopside) rarely occurs except as a kernel in the céntre of the hornblende individuals. Biotite is usually present in very small quantities. Sphene of characteristic shape, apatite in comparatively large crystals, and magnetite, as accessory minerals, complete the list of constituents.

Augite syenite.—The dark coloured augite syenite, which occupies so large an area in the vicinity of Peninsula, is one of the most interesting of the rock-types represented in this district. It varies in colour from dark brownish-grey to almost black. Transitional phases are dull

reddish-grey or soapy brown. Freshly broken surfaces exhibit the brightly gleaming surfaces of plate-like or lath-shaped feldspar. These idiomorphic feldspars are frequently Carlsbad twins, often with a handsome bluish shimmer. The feldspars are greatly predominant, but, owing to their prevailing dark colour, which is due to inclusions, the relative paucity of bisilicate material is not noticeable except upon close inspection. The rock is coarse in texture, the feldspars averaging a quarter of an inch ((·6 cm.) in length and breadth, but only a tenth of an inch (·25 cm.) in thickness.

The mineral constituents are principally feldspar and pyroxene with subordinate amounts of hornblende, biotite and olivine; magnetite, apatite and pyrite are accessory constituents. The feldspar is for the most part a microperthitic intergrowth of albite and orthoclase, although natron-orthoclase, orthoclase and plagioclase are also present, but are relatively unimportant. Pyroxene is the characteristic dark mineral. In the Peninsula area this mineral shows a pale brown interior with a deep green border, and is undoubtedly one of the aegirine-augite series. In outcrops, near Coldwell as well as between the crossing of Little Pic river and Middleton station, the augite is pale violet, sometimes bordered by brown barkevikite. In the western part of the Peninsula area the pyroxene is commonly diopside, frequently surrounded by a border of brown barkevikite and bright blue arfvedsonite. Olivine is usually present but is not an abundant constituent except in the vicinity of Middleton. The rock in the cutting east of Penisnula near Craig's gravel pit contains an olivine which, between crossed nicols, resembles sphene. It was identified by Brögger, who states that it corresponds very closely with the olivine present in the laurivikite of southern Norway. Hornblende, usually barkevikite, occurs sparingly. Arfvedsonite is also noticeable, and very occasionally riebeckite, distinguished by its pleochroism in deep bluish colours. Biotite is an unimportant constituent. Magnetite, pyrite, apatite, and bluish fluorite are the accessory constituents present.

White feldspathic variety.—The white feldspathic variety, which is closely related to the nepheline syenite occurs about the centre of Big Pic island. The white feldspar, which is by far the most abundant mineral, is chiefly orthoclase or albite or graphic intergrowths of these.

The chief of the dark coloured constituents, which are usually grouped together, is a very deep brown hornblende. A few scales of muscovite and rare fragments of pyroxene enclosed in hornblende were noticed. Magnetite and apatite are conspicuous associates of the hornblende and biotite. Nepheline, usually decomposed to hydronephelite. is sometimes present in very small amount.

Nepheline syenite.—The nepheline syenite may in a general be described as a medium grained rock of granitic habit varying from pale grey to dark grey in colour. Many outcrops are pinkish or purplish owing to the relative abundance of hydronephelite, a decomposition product of the nepheline. When present in very considerable amount, as is often the case, it produces a striking and beautiful rock. Gneissoid structure is very uncommon, but occasionally a peculiarly banded structure, due to the segregation chiefly of the darker coloured minerals, is in evidence. Weathered surfaces are characteristically pitted owing to the rapidity with which nepheline decomposes.

The most abundant mineral constituent is feldspar. Nepheline sometimes constitutes one-sixth of the whole rock mass (hill east of Coldwell station). Hydronephelite is always present, while hornblende and magnetite and the less abundant pyroxene are also readily distinguishable. In most instances the coloured constituents are very subordinate, but in some cases they form the bulk of the rock.

All the feldspars belong to the natron-orthoclase-microperthite series. All gradations from undoubted pure natron-orthoclase to distinct microperthitic intergrowths of orthoclase and albite are found. Nepheline is always the last mineral constituent to crystallize, occupy ing the irregular interspaces between the other constituents. As a rule it is usually decomposed in part, or altogether, to hydronephelite. This orange-red hydronephelite is the most striking mineral constituent of the nepheline syenite. It is undoubtedly the orange-coloured nepheline of the original descriptions by Logan. This mineral is very abundant and characteristic. It occurs both in simple individuals, often of microscopic dimensions and sometimes with centres of unaltered nepheline still remaining, and also in aggregates of several individuals up to half an inch (1·27 cm.) or even more in diameter.

Sodalite is almost entirely absent from the nepheline syenites of this area. It does occur, however, in the highest hill southwest of Coldwell, on Pic island and about two miles (3·2 km.) north of mile post 78.

Hornblende is much the most abundant ferromagnesian constituent. There is a green and a brown variety. The optical properties of the brown hornblende suggest barkevikite, although no confirmatory chemical analysis was undertaken. The colouring of the individuals is by no means uniform, but pale interiors with deeply coloured borders are the rule; often the crystals have a spotted appearance. Pleochroism is very marked, varying from greenish yellow to chestnut brown in the brown variety, and in the green hornblende from straw yellow to deep green. Poikilitic structure mainly with feldspar is common. Pyroxene, ranging in composition from deep green aegirine-augite to pale coloured diopside, and often surrounded by a border of hornblende is usually present even in specimens that are rich in hornblende. The pleochroism of the aegirine-augite is very strong and from yellow to grass green. Aegirine-augite is especially characteristic of varieties rich in nepheline. Frequently it forms a rim around the paler coloured diopside. Biotite is by no means a common constituent, although in one locality (west part of Coldwell peninsula) it is the chief ferromagnesian mineral. Magnetite as an inclusion is always present, and comparatively large apatite crystals are common. Occasionally muscovite, sphene, pyrite and purple fluorite are noticeable.

Essexite, Olivine Gabbro and Picrite.—The basic rock of the Coldwell massif are undoubtedly the oldest of the series. They are very variable in composition. The more common type seen in the neighborhood of Coldwell is a dark grey rock of medium texture with gleaming crystals of biotite. The dark coloured constituents represent more than three-fourths of the whole rock mass. Thin sections show augite, olivine, biotite, hornblende, labradorite, some orthoclase, occasionally nepheline and much magnetite with apatite as the chief accessory constituent.

Most of the dykes of the region are small, ranging from a couple of inches (5 cm.) to four feet (1·2 m) in width. They are usually of a slate grey colour and very fine grained. Many of them are intermediate in composition between

camptonite and essexite. The camptonites are the principal dykes of the area. They are composed chiefly of hornblende, biotite, feldspar, magnetite, some pyrite, very little apatite and secondary calcite.

RELATIVE AGES OF CHIEF TYPES.

According to Brgöger, the rocks of the Norwegian syenite area were derived from a common magma basin, through a succession of irruptions beginning with the basic rocks and forming a continuous series to the most acid granites. He also states his belief that the later basic dykes found cutting the main rock mass represent the final depletion of the original magma basin. According to Kerr, the oldest rocks of the Port Coldwell complex are the basic picrites, olivine gabbros and essexites; while as in Norway, the youngest rocks of the region are the narrow basic dykes, camptonites, etc. Next in order of age to the oldest basic intrusives are the augite syenite or laurivikite, the red hornblende syenite, and the nepheline syenite.

The difficulties of assigning a definite succession, for the whole area can be understood only by those who have made the attempt in other districts. To the writer of this account, which is an epitomized statement of Kerr's conclusions, it seems that the general succession proceeding from the oldest to the youngest was as follows:—

1. Picrite, olivine gabbro and essexite.
2. Augite syenite or laurivikite.
3. Nepheline syenite.
4. Red hornblende syenite
5. Quartz syenite.
6. Camptonites, etc.

These syenites are all intrusive into the greenstones and greenstone schists of the Keewatin and, so far as can be judged, merge without any sharp line of delineation into granites usually classified as Laurentian.

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COLDWELL TO PORT ARTHUR.

BY

A. L. Parsons.

ANNOTATED GUIDE. (Coldwell to Loon).

Miles and Kilometres from Sudbury.

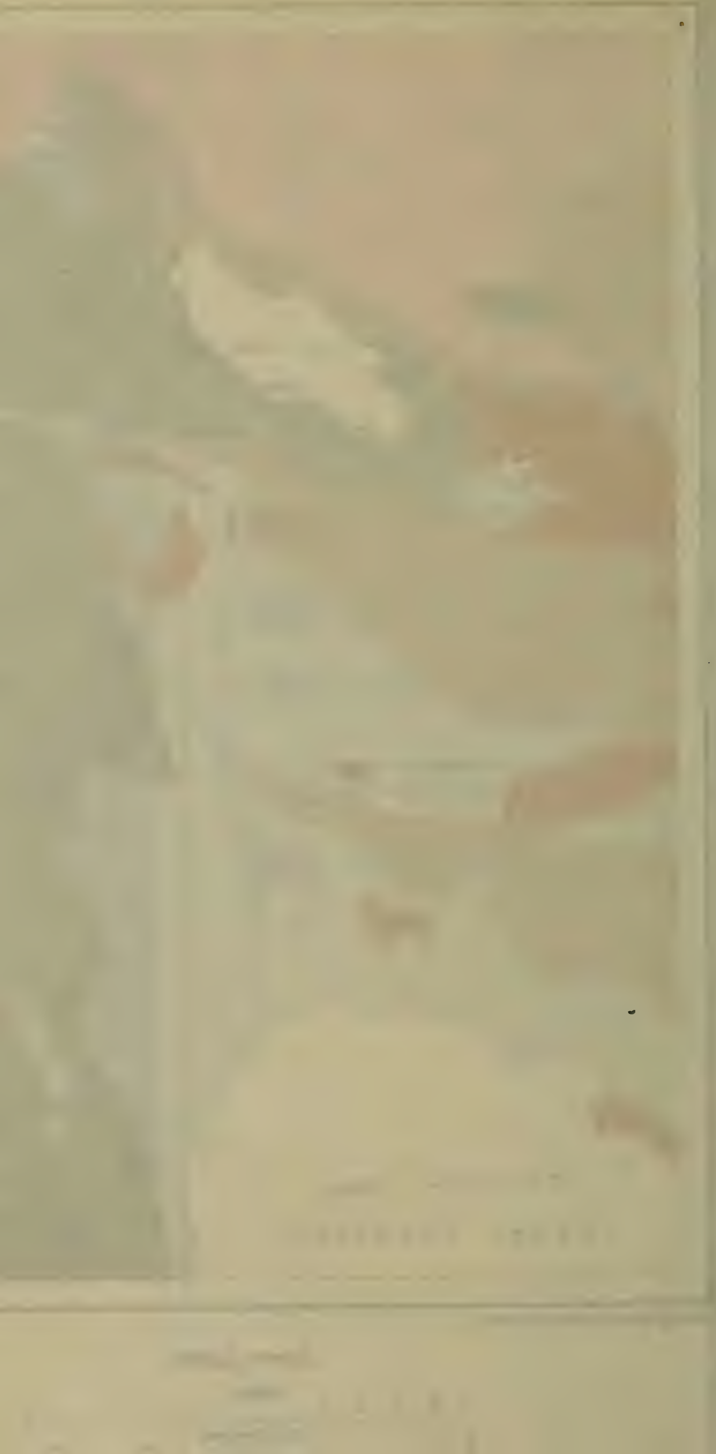
391 m. **Middleton**—Altitude 691 ft. (210·6 m.).
629 km. From Middleton the railway passes through a region underlain by Keewatin rocks, which extends to Jackfish, a fishing village on Lake Superior.

407 m. **Jackfish**—Altitude 632 ft. (192·6 m.). Near
658 km. Jackfish station the contact of the Keewatin

Geological Survey, Canada.

Loon Lake

Miles
1 3/4 1/2 1/4 0 1 2
Kilometres
1 1/2 0 1 2 3 4 5



Miles and Kilometres.

and Laurentian is seen. The interval between this station and Schreiber is occupied entirely by Laurentian rock.

426 m. 688·5 km. **Schreiber**—Altitude 993 ft. (302·6 m.). Keewatin trap extends with some interruptions for about five miles (8·0 km.) west of Schreiber, after which the Laurentian and Pleistocene gravel deposits extend almost uninterruptedly to Hartley, where the Animikie is first seen.

From Hartley most of the rock exposures as far as Port Arthur are of Animikie and Keweenawan, with underlying Laurentian bosses. Occasionally Keewatin rocks are present, but these are a minor feature. Many gravel deposits, exhibiting cross-bedding, occur. The best views of the Animikie and Keweenawan rocks are obtained near Kama, Nipigon and Red Rock.

489 m. 787 km. **Nipigon**—Altitude 681 ft. (207·5 m).

531 m. 854·5 km. **Loon**—Altitude 1,000 ft. (304·8 m.).

THE PRE-CAMBRIAN GEOLOGY OF LOON LAKE DISTRICT.

Introduction.

The region around Thunder bay was first described geologically in a brief report by Sir W. E. Logan, (**1**), who also gave a more extended description of the rocks at a later date (**2**) and mapped the formations as they were then known(**3**). Dr. R. Bell (**4**) explored much of this region in 1869 and described many of the rocks. He also prepared a map on which, however, geological boundaries are lacking. The first report accompanied by a detailed map was prepared by E. D. Ingall (**5**), who not only described quite minutely the silver-bearing rocks of the region, but gave a description of the silver mines. Later the investigation of the iron ores of this region was taken up by W. N. Smith (**6, 7**) upon whose work the following classification of the rocks is based.

Pleistocene	Glacial drift.
Unconformity.	
Keweenawan (Nipigon)	Conglomerate, sandstone, marl; diabase sills.
Unconformity.	
Upper Huronian (Animikie)	Iron-bearing formation and black slates.
Unconformity.	
Lower Huronian	Greywacke, greenstone, granite.
Unconformity.	
Keewatin	Green schists, greenstones, mashed porphyries.

Mr. Smith's article in the Bureau of Mines report was unaccompanied by a map, though one was published in the Mining World and was used with minor changes by L. P. Silver the next year in his report on the Animikie iron rangs (**8**). In accordance with the findings of the Special Committee on the Lake Superior region (**9**) Mr. Silver altered the legend given by Mr. Smith, so that his interpretation of the geological sequence is as follows:—

Pleistocene	Glacial drift, residual clays, beach sands and gravel.
Unconformity.	
Logan Sills	Diabase, diorite or gabbro intruding all the following formations.
Igneous contact.	
Keweenawan (Nipigon)	Conglomerate, sandstone, impure marls.
Unconformity.	
Upper Huronian (Animikie)	Iron - bearing formation, black slates, impure limestone and quartz conglomerate.
Unconformity.	
Middle Huronian	Granite (igneous contact).
Lower Huronian	Conglomerate, greywacke, greenstone, quartz porphyry, amphibolite.
Unconformity.	
Keewatin	Quartz porphyry.

The map accompanying Mr. Silver's report has been used in the preparation of the accompanying sketch map

though the correctness of certain portions of it may be questioned. To the writer it would seem that a considerable portion of the rock mapped as Lower Huronian should be included in the Keewatin, particularly that situated about one half mile south of Loon station, near Wylie's camp. The age of the granite also may be called in question by some but, if the definition of the Special Committee on the Lake Superior region be accepted, it would not be classed as Laurentian without some explanatory note.

Description of Formations.

Pleistocene.—Of this formation little can be said, as no detailed work has been done toward differentiating the various types of deposits, which include extensive areas of glacial drift and assorted sands, clays and gravel.

Keweenawan.—This series consists of extensive deposits of conglomerates, sandstones and marls. Some writers also include the Logan sills. In the area visited by the excursion no extensive deposits of sandstone are seen but the other features are well shown. In a cut on the Canadian Pacific railway one mile west of Loon an exceptionally fine outcrop of conglomerate, interbedded with small bands of sandstone is exposed. The boulders of the conglomerate are principally granite, though greywacke, iron formation and slate (Animikie), and amphibolite also occur. This conglomerate is cut by two narrow dykes of trap presumably connected with the Logan sills. The marls and impure sandstones are extensively developed near Silver lake, and in these are numerous veins sometimes containing sphalerite, galena and barite, but more frequently containing amethyst.

Possibly the most striking feature of this series is the trap formation known as the Logan sills. These intrude not only the older rocks but the Keweenawan as well, and are referred by some writers to a later age, while others look upon them as an integral part of the Keweenawan. These sills seldom exhibit their intrusive nature but appear as great lava sheets lying in a horizontal position over the Keweenawan and Animikie. The intrusive contact is best seen at Port Arthur, but near Loon the Animikie slates and iron formation are occasionally found overlying the diabase sills.

Upper Huronian (**Animikie**).—This series has been divided by Silver into the following divisions.

1. Black slate.
2. Upper iron formation.
3. Slate (somewhat calcareous.)
4. Thin bedded impure limestones.
5. Iron formation proper.
6. Quartz conglomerate.

The last of these is not more than six inches (15 cm.) in thickness, where it has been seen in this vicinity and consists of pebbles of vein quartz.

The other five members of the series are reduced by Mr. Smith to four divisions by omitting the thin bedded limestones which, according to an analysis by Mr. A. G. Burrows (**8,** p. 163), would appear to be ankerite in which the iron has been oxidized to ferric oxide. Mr. Smith looks upon these four divisions as representing one "continuous period of deposition during which the conditions varied between those of chemical and probably also organic sedimentation, producing the iron-bearing formations, and those of mechanical sedimentation with the production of the slates." (**6**).

The upper black slate has not been found around Loon lake, though in other places it is well developed. The upper iron formation is a thin bedded cherty iron carbonate resembling in texture the jaspilite of the Vermilion and Mesabi ranges in Minnesota. 'It varies in colour from dark grey to very light-coloured, although the most characteristic phase..............is a dark and light-banded rock.'(**6**)

The lower iron formation consists essentially of taconite, and all stages in the formation of iron ore may be observed in this formation. The slate between the upper and lower iron formations has not been described nor has any outcrop been located either on a published map or in printed descriptions.

Granite.—North of Loon lake is a series of hills of granite intrusive into the rocks which have been assigned to the Lower Huronian and the Keewatin. These hills are dome shaped and have been denuded by glaciation. That the original form of the intrusive mass was not materially different from the present form is shown by the presence of contact breccia over the surface of the hills. These masses are similar to if not identical in composition

with the granites that throughout this region have been referred to the Laurentian.

Lower Huronian and Keewatin.—Considerable difference of opinion is shown by those who have made a careful study of the formations in this region as to the dividing line between these two series. The writer has visited only one of the outcrops, which lies about a half mile south from Loon station and in his opinion it would be referred to the Keewatin if seen in a region where the bulk of the rock belonged to that age. The difficulty of making a distinction between the rocks of the two formations in this region is increased by the highly altered condition of the rocks, few of which show much trace of their original character. The two series consist of quartz porphyry exhibiting flow structure; greywacke, which has been altered to a considerable extent to schist; greenstone and a conglomerate, which, from the one illustration given (**8**) and the description of the constituents, may be compared with the Keewatin agglomerates of the friction breccia type.

ITINERARY.

In a southeasterly direction from the station at Loon is an outcrop of highly altered Keewatin or Lower Huronian which is exposed near a fork in the road. At Wylie's camp the same rock is well exposed. This rock shows considerable contortion and some minor faulting and is very similar to the more highly altered phases of the Keewatin. Along a trail to Silver lake from this exposure Animikie iron formation is well exposed at several places. The alteration of taconite to iron ore is well exemplified in an exposure on the south side of the trail and in the old shaft near Flaherty's camp. Good hematite (kidney iron) and taconite are well exposed at the tunnel on Flaherty's claim. Near this tunnel a fault is said to separate the Animikie from the Keweenawan. Some time will be devoted to the contact of Animikie and Keweenawan and to the character of the more marl-like material of the Keweenawan.

Returning southward along the trail the contact of the Animikie slates with the Logan sills may be noted. Continuing along the trail the Animikie may occasionally be found lying on the top of this sill. A view of Lake Decep-

tion well illustrates the type of lake scenery to be found in the Keweenanwan and Animikie rocks. Occasionally taconite, along with the Animikie slate, is found overlying the sill. A magnificent view of Thunder bay and Thunder cape can be seen from one of the more open spots a little farther along. In descending from this last point to the valley the contact of the sill with the underlying Animikie slates is passed. To the north is another exposure of taconite upon which some prospecting has been done. One mile west of the railway station, in a railway cut, is a remarkable conglomerate intersected by two small dykes apparently connected with the Logan sills.

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ANNOTATED GUIDE—(Continued).

Miles and Kilometres from Sudbury.

One mile (1·6 km.) west of Loon a remarkable conglomerate is exposed in a railway cut. From this point to Port Arthur the rock is of diversified character, including Laurentian, Keewatin, Animikie and Keweenawan, with no very striking exposures of any of them.

554 m. 891·5 km. **Port Arthur.**—Altitude 608 ft. (189·3 m.).

THE PRE-CAMBRIAN GEOLOGY OF PORT ARTHUR DISTRICT.

History of Exploration.

Port Arthur district has been widely known for many years because of its silver mines, which were at one time large producers. Of these, Silver Islet mine was the most noted, not only for the amount of silver obtained from it, but also for the Frue vanner which was invented by men connected with the mine and first used in the concentration of Silver Islet ore.

The first important description of this district was prepared by Sir. W. E. Logan (**1**). This was followed by a more extended description and a geological map by the same author at a later date. (**2**).

The explorations of Dr. R. Bell along the north shore of Lake Superior in 1869 (**3**) added materially to our knowledge of the rocks of this region, but unfortunately the map accompanying the report shows no geology so that it is difficult to estimate the scope of his work.

The first important work dealing in detail with the silver deposits was done by E. D. Ingall (**4**), who shows in a sketch map the geological boundaries as then known and the location of the mines. He also prepared a geological and topographical map of Silver Mountain mining district which gives the essential features of the geology of this region. A resumé of this report is given by Dr. W. G. Miller (**5**) to show the similarity of the silver deposits of Cobalt with those of Port Arthur district.

The latest work in this region was done by Dr. N. L. Bowen (**6**), whose report supplements that of Mr. Ingall by including the later mine development.

Geology of the District.

The geology of Port Arthur district is simpler than it is near Loon lake, because of the absence of the Keewatin and Lower Huronian . Only the Pleistocene, Keweenawan and Upper Huronian or Animikie occur in the immediate vicinity of Port Arthur. Laurentian and Lower Huronian rocks are to be found within four miles (6·4 km.) to the north of the city but are not exposed within the area visited by the excursion.

Pleistocene.—The Pleistocene has not been carefully studied, but consists not only of till, but also of assorted sands and gravels which frequently show marked cross-bedding. This latter feature is to be seen at many of the gravel pits along the railways where excavation has been recently done.

Diabase sill intrusive into slate; Current River Park, Port Arthur.

Keweenawan.—The Keweenawan in this region consists largely, if not entirely, of great masses of diabase which were intruded into the Animikie slates and iron formation in the form of extensive sills, known as the Logan sills. These sills have a marked effect upon the topography of the region, giving rise to flat topped hills, the upper parts of which are very precipitous, though the lower parts have gentle slopes due in part to the formation of talus. It was formerly supposed that these sills were surface flows as they were found capping the hills, but Dr. A. C. Lawson (7) showed that they were intrusions.

This rock is well shown in Current River park where a large area of rock was stripped of its covering of recent deposits by a flood caused by the bursting of a dam. Most of the surface rock so exposed is compact diabase, but numerous patches of black Animikie slate, ranging in thickness from a few inches to several feet, are scattered about over the surface. This slate is considerably baked by contact netamorphism, and the sill itself is finer grained near the contact than elsewhere, though at no part does it become very coarse grained. In some places through segre-

Black Animikie slate; Prospect Street, Port Arthur.

gation of the phenocrysts of labradorite the rock grades from a typical diabase into masses from two to ten feet (.6 to 3 m.) in diameter having the composition of anorthosite.

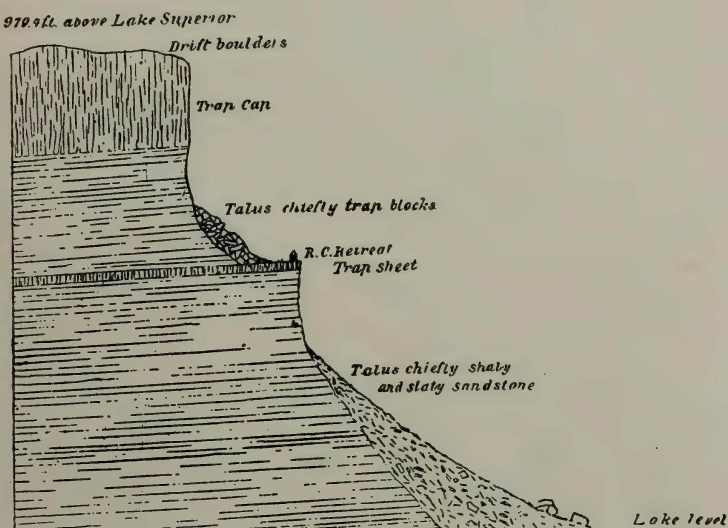
Animikie.—The Animikie or Upper Huronian is essentially a sedimentary series and is important as a silver and iron-bearing formation. The complete section is not well exposed at Port Arthur, but two of the members

are well developed. The complete series is best observed near Kakabeka falls on Kaministiquia river. (**6**) It consists of (1) iron formation, including taconite, jasper, chert etc., (2) black slate, (3) grey quartzite with grey slate and (4) grey argillite. This agrees substantially with the sequence given by W. N. Smith (**8**) though the nomenclature is slightly different. It however, omits the basal conglomerate of L. P. Silver (**9**) as well as his thin bedded, impure limestone, which apparently are to be grouped with the iron formation.

Slates exposed in Stewart and Hewitson's quarry, Port Arthur.

This series is important economically, containing silver veins and extensive deposits of iron ore. Heretofore the iron deposits have not been so important in the Animikie of Ontario as in the same formation in Minnesota and but little mining has been done. Prospecting has however revealed several deposits of good ore of greater or less extent. In Port Arthur district, interest in this series has centered chiefly upon the black slates in which nearly all

the silver discoveries have been made. The silver is found in fissures in this rock near the intrusions of Keweenawan diabase, and in some cases the veins have crossed the diabase as well as the slate. The dark colour of the slate is largely due to the presence of carbonaceous matter which is thought to have been an important factor in the precipitation of the silver, for the silver is said to be always accompanied by carbonaceous matter.



Section through Mt. McKay near Fort William, Ont. The trap here bears a similar relationship to the slaty series to that which it has in the Cobalt area. Some silver veins in the Port Arthur area cut both the trap and the slate. (After Dr. A. C. Lawson.)

The most noted mines of this vicinity are the Silver Islet, Silver Mountain, Beaver, Badger, and Porcupine. None of these have been worked to any great extent since the fall in the price of silver in 1892.

Itinerary.

At Current River park the Keweenawan traps and overlying slate are first noted. Usually the slate is not more

than a foot in thickness, but near the Canadian Pacific Railway track there is an exposure several feet in thickness.

Returning to the city an excellent view of Mt. McKay may be seen from the Lookout near the collegiate building. By reference to the accompanying section the effect of the diabase sills upon the form of the mountain may be observed. The Lookout itself is interesting in that it is built of materials representing most of the Pre-Cambrian rocks of the region. An outcrop of black Animikie slates occurs near the corner of Prospect Street and the car line, and at the corner of Hebert and College Streets is a good exposure of taconite. Slates and Keweenawan trap are well exposed in the Stewart and Hewitson's quarries at the end of Hill street, and in the former, slaty cleavage is well developed. Silver was found in a vein in this quarry. The large quarry near the crushing plant shows several well defined veins, filled with calcite, fluorite and barite, which penetrate both slates and diabase.

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PORT ARTHUR TO WINNIPEG VIA CANADIAN NORTHERN RAILWAY.

BY

W. L. UGLOW.

INTRODUCTION.

The excursion over the Canadian Northern railway from Port Arthur to Winnipeg affords an opportunity of seeing an unusually complete Pre-Cambrian section. Within this distance of 230 miles (370 km.) every Pre-Cambrian series that had been differentiated in the Lake Superior region is exposed to a greater or less degree. In addition, the base of the section is formed by the Coutchiching series, one that is rare in other localities, and which is claimed by those who have studied it specially, to be even older than the Keewatin. The area also contains, in exposures of fossiliferous Lower Huronian limestone, the oldest known records of life.

A few broad topographic features should be mentioned at the outset. Two chief types of topography are well represented: the rocky lake country, and the alluvial plain. Generally speaking, the former occupies the eastern part of the region traversed, although the first 25 miles (40 km.) of the trip are across the post-glacial flood-plain of Kaministiquia river. West of Rainy lake, rock exposures and hills are rarely seen, and the level country passed through is in part the alluvial plain of Rainy river, and in part the bed of glacial Lake Agassiz, (**12**) which continues to Winnipeg.

The most recent classification of Canadian Lake Superior geology is that by Dr. Andrew C. Lawson in his new report (**6**) on the Rainy Lake region. For purposes of reference his table of formations is reproduced below, in full. What are believed to be the equivalents of the various series in the nomenclature of the International Committee and of the United States Geological Survey are included in parentheses.

Algonkian (No equivalent).	Keweenawan (Keweenawan).
	Unconformity.
	Animikie (Upper Huronian).

Eparchacan Interval—Unconformity between the Middle and Upper Huronian.

	Algoman (granites intrusive into the Lower and Middle Huronian).
	Irruptive contact.
	Seine series (Middle Huronian).
	Unconformity.
Archaean	Steeprock series (Lower Huronian).
(No equivalent)	*Unconformity.*
	Laurentian (Laurentian).
	Irruptive contact.
	Ontario Keewatin (Keewatin).
	(Keewatin) Coutchiching (No equivalent?).

A short quotation (**6**) will explain Dr. Lawson's method of subdividing the series below the Cambrian: "Upon the vast peneplain resulting from degradation during the Eparchaean Interval were deposited the Animikie sediments. The Animikie is thus separated from the Huronian by an enormous interval of geological time. On the far side of that interval the earth's crust was affected by plutonic activities, involving the Coutchiching, Keewatin and Huronian similarly, which have not recurred in the region so far as is known on the near side of that interval. In other words, the Huronian is allied in its geological history with the Coutchiching and Keewatin, and is part of the Archaean, while the Animikie (Algonkian) is allied with the Palaeozoic."

In order to complete the geological sequence exposed along the Canadian Northern railway, there should be mentioned an outcrop of Richmond fossiliferous limestone (Ordovician), found by Dr. Lawson, about six miles (9·6 km.) west of Fort Frances, and believed by him to represent an outlier of the Palæozoic rocks more abundantly exposed in the valley of the Red river in Manitoba.

ANNOTATED GUIDE.

(Port Arthur to Iron Spur.)

Miles and Kilometres.

0·0 m. 0·0 km. **Port Arthur**—Altitude 607 ft. (185 m.).

3·0 m. 4·8 km. **Fort William**—Altitude 612 ft. (186 m.). These two cities, commonly known as the "Twin Cities," are located at the head of the Great Lakes system of navigation. The rocks underlying Port Arthur and Fort William consist of apparently flat-lying Animikie sediments (slates, indurated shales, cherty dolomites, etc.) and Keewenawan diabase sills. The characteristic topography produced by the erosion of this group of rocks can be seen in the islands and shores of Thunder bay. The flat-topped, steep-sided outlines of these hills are produced by cappings of diabase which have protected from erosion the underlying sediments. In some sections more than one sill may be observed.

Leaving Port Arthur, the train takes a south-westerly course across the post-glacial flood-plain of the Kaministiquia river to the towns of Fort William and Westfort. A short distance to the south of Westfort, McKay Mountain rises to a height of 1,600 feet (488 m.) above the sea, and exhibits pronounced mesa-like outlines. The horizontal attitude of the sills and Animikie sediments, as well as the vertical columnar jointing of the former, may be readily observed from the train. After passing Westfort, the soft, rounded outlines and roche montonée topography characteristic of the southern part of the Archæan terrane, appear in the far distance to the north and northwest.

23·4 m. 37·7 km. **Kakabeka Falls**—Altitude 912 ft. (278 m.). Up to this point, and for some distance beyond, the railway traverses the flood-plain of the Kaministiquia, and the total absence of rocky hills near at hand is a striking feature . Near the station, however, the Kaministiquia drops a short distance over Archæan granite-gneiss, and

Miles and Kilometres.

for half a mile (0·8 km.) below flows down a low gradient to the great falls, which are over a cliff of horizontal Animikie indurated shales, 150 feet (45·7 m.) high. The Animikie-Archæan unconformity is not well exposed, although traces of a basal conglomerate are found plastered on horizontal surfaces of the granite gneiss. But the structural discordance between the comparatively undisturbed Animikie strata

Animikie indurated shales, Kakabeka falls.

and the highly sheared Keewatin greenstones, which outcrop a short distance away, is sufficient proof of uncomformable relations.

82·3 m.
132·5 km.

Kashaboiwe. From this locality westward to the vicinity of Kashaboiwe a belt of Keewatin greenstone and felsite schists is followed. In association with this belt are lenses of iron formation which constitute what is known as the Mattawin iron range. The iron-formation is generally banded in character, and deposits of clean ore

Miles and Kilometres.

occur of both the magnetite and hematite types. The granite-Keewatin contact is crossed just west of Kashaboiwe, and the greyish-white granitic hills are a prominent topographic feature from this point to near Huronian.

97·1 m. 156·2 km. **Huronian.**—The next 25 miles (40 km.) to Kawene station afford an excellent opportunity to observe the intrusive relations between an Archæan granite-gneiss and a distinctly sedimentary series. Sufficient detailed work has not yet been done in this part of the region to definitely correlate these rocks, but, in all probability, they are the Algoman granite and the Seine sedimentary series, which will be examined in detail at Iron Spur. An excellently developed contact breccia continues with abundant exposures for the whole distance, and may be readily observed in a general way while en route.

121·6 m. 195·7 km. **Kawene.**—At Kawene the contact swings south of the track, and from here to mile post 126 excellent exposures of the Seine series occur on both sides. At this mile post, the contact is again crossed, and the Algoman granite continues to Iron Spur.

123·8 m. 206·4 km. **Iron Spur**—Altitude 1,400 ft. (427 m.) From this point a trip is taken three miles (4·8 km.) along a spur line to the site of the Atikokan iron mine to observe the irruptive contact between the Algoman granite and the Seine series, and to examine the high-sulphur iron ore-body.

GEOLOGY OF THE VICINITY OF IRON SPUR.

General Statement.

The general elevation of the country surrounding Iron Spur is between 1,300 and 1,500 feet (396 and 457 m.) above sea-level, or from 700 to 900 feet (214 to 275 m.) above Lake Superior. The outstanding features of the physiography are the low rounded hills that characterize the Pre-Cambrian in this part of Canada. The intervening areas consist occasionally of glacial drift, but more usually of alluvial material, forming what are commonly known as muskegs.

The geological series represented in the vicinity are, in descending sequence, according to the nomenclature of Dr. Lawson:

Archæan	Algoman
	Irruptive contact.
	Seine series
	Unconformity.
	Keewatin.

Keewatin.

Exposures of this formation are rather rare in the immediate neighbourhood, but occur a short distance north of Atikokan river as part of a N. E.–S. W. belt. The rock types represented are greenstone, gabbro, felsites (quartz-porphyries) and their schistose equivalents.

Seine Series.

This consists of a group of rocks, which typically consists of dark-coloured micaceous quartzites, quartz slates and greywacke slates, grading into sericitic schists. Their appearance, both on fresh and weathered surfaces is decidedly sedimentary. In other localities they are found to be unconformably above the Keewatin and Laurentian.

Algoman.

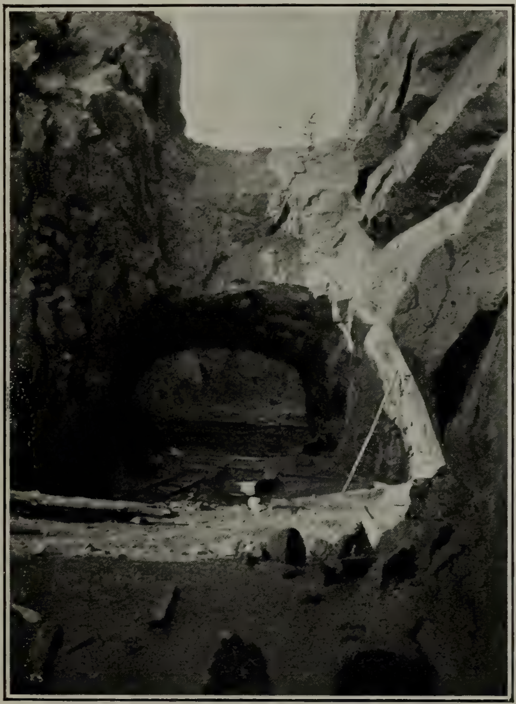
This is primarily a biotite granite of medium to coarse-grained texture. It varies between granite and syenite types, and usually contains phenocrysts of acid feldspar. Previous to the summer of 1911 it was mapped by Canadian geologists as part of the Laurentian. But now, in this locality, a small oval-shaped area is differentiated, owing to the fact that it intrudes a well-defined, water-deposited series. It is believed that a considerable part of the rocks mapped as Laurentian in this part of the province is really younger than the Seine series and therefore of Algoman age.

The area was mapped in 1897 by W. McInnes and the late W. H. C. Smith for the Geological Survey as part of the Seine River sheet. Since that time Dr. A. P. Coleman and others have visited the region in connection with studies of the Lake Superior iron ores. The most recent work in the area was done by Dr. Lawson during a visit

to this locality in the summer of 1911, and by the late Dr. J. D. Trueman in the early summer of 1912.

PARTICULAR DESCRIPTION OF POINTS TO BE VISITED.

Ore-body at the Atikokan Iron Mine.—The iron ore deposit occurs in a rocky ridge running approximately east and west, just north of the track and about 2·75



Open cut, Atikokan iron mine, Iron Spur, Ontario.

miles (4·4 km.) from the beginning of the spur. The rocks in the vicinity of the mine are very imperfectly exposed. The ridge itself is isolated, being bounded by a muskeg on the south, and separated by a valley from a ridge of Keewatin greenstones to the north.

The ore is magnetite, rather freely supplied with sulphides, chiefly pyrite, but also including traces of chalcopyrite. It occurs as a series of overlapping lenses, separated from one another by walls of greenstone, and bounded on the north side by a wall of highly sheared acidic rocks. Associated with the ore and interlaminated with it, are beds of greyish-white chert and dark green slate. In places along the strike, especially near the east end, narrow beds of ore, chert and slate may be seen interlaminated with each other. The ore-bodies and associated rocks have a common strike and dip, the later varying from vertical to 60° north.

The following account of the origin of the ore-body is given by Dr. Lawson in a forth coming report of the Geolical Survey of Canada, and on account of its dissimilarity to other interpretations is worthy of quotation almost in toto:

"Iron ores occur either at the contact or close to it where there is no conglomerate. The ore and the conglomerate thus appear to be in a certain sense complementary features of the base of the Seine series. It is interesting to note in this connection that the pre-Seine surface of the Keewatin greenstones, where it emerges from beneath the Seine series, is commonly heavily charged with carbonates (including siderite or ankerite) and limonite. This condition in some sections obtains for several hundred feet away from the contact, and with little question it represents the effect of the weathering of the Keewatin surface in pre-Seine or early Seine time. It suggests a supply for the iron ore that is found in workable bodies and in less important prospects along the line. The concentration may have been effected in bogs in early Seine time, a possibility which harmonizes with the absence of conglomerate at such points along the contact; or it may have been concentrated by underground circulation after the burial of the weathered and iron-rich surface by the Seine sediments."

Particular interest attaches to this particular occurrence, because of the successful attempt of the company to use an ore which is not only hard but also markedly rich in sulphides.

The mine has a good surface equipment, and the company owns an up-to-date blast-furnace at Port Arthur which was designed and erected primarily for the treatment of

the high-sulphur Atikokan ores. Before being smelted these ores are specially treated to eliminate the sulphur, so far, with remarkable results.

Irruptive Contact of the Algoman Granite with the Seine Sedimentary Series.—The phenomena to be observed in this connection extend from a point on the railway spur one eighth of a mile (0·2 km.) from the main line along the spur to the main line, and then for an eighth of a mile (0·2 km.) westward along the main line. On returning from the iron mine, the following points in connection with the intrusion can be noted in the order given.

1. Dykes and stringers of granite cut the dark-coloured, anamorphosed phase of the Seine series, and frequently traverse it across the bedding.

2. Angular to rounded fragments of the altered Seine rocks are abundant within the granite mass.

3. Assimilation of these inclusions by the intrusive is shown by its abundant content of hornblende and general adoption of a basic phase near the intruded series.

4. A short distance from the contact, the Seine rocks resemble a dark-coloured gneiss, rich in quartz and biotite with stringers of lighter-coloured, more or less feldspathc material.

5. The passage from this anamorphosed variety through a less altered one to the normal phase may be well followed by observing the exposures in two railway cuts, about an eighth of a mile (0·2 km.) along the main line and just west of the section house. The character of the anamorphosed Seine series should be especially noted in order that it may be compared with that of the Coutchiching series in the Rainy Lake area.

ANNOTATED GUIDE (Iron Spur to Atikokan).

After leaving Iron Spur occasional exposures of the Seine series, separated by stretches of muskeg occur on both sides of the line. The valley of Atikokan river follows rather closely from the crossing just west of Iron Spur.

Miles and Kilometres.

131·6 m. 211·9 km. **Hematite**—Altitude 1,360 ft. (415 m.) From this point westward to Atikokan, the railway marks approximately the contact of the Seine with the Keewatin group. The latter stands out in much weathered exposures of greenish-coloured schists in the hills just to the north of Atikokan river. To the south and usually in the rock-cuts along the railway may be seen the quartzites and quartz slates of the Seine series. The iron formation of the Atikokan range which outcrops at intervals on both sides of the track is probably an extension of the ore-bodies northeast of Iron Spur. Half-way between mile posts 139 and 140, there seems to be an actual contact between the Seine series and the Keewatin but no trace of a basal conglomerate could be found. With the exception of a short space just east of mile post 141, occupied by Keewatin greenstones, exposures of the Seine series continue more or less intermittently to Atikokan.

142·4 m. 229·5 km. **Atikokan**—Altitude 277 ft. (389 m.). From this point a side excursion occupying half a day is taken to Steeprock lake to examine the fossiliferous limestone and the structural features of the Steeprock sedimentary series of the Archæan.

GEOLOGY OF THE VICINITY OF STEEPROCK LAKE.

General Description.

The physiographic features of this region are typical of those in the southern part of the Pre-Cambrian terrane. The rocky lake country, which is here well exemplified, presents the character of a peneplain. Regarded on a large scale, it is remarkably flat and devoid of prominent elevations, but, when considered in detail, the surface is extremely uneven and hummocky.

The general geology of the region was partially worked out by Dr. Lawson for the Geological Survey in the summer

of 1911, and on his report (**7**), recently published as a memoir of the Survey, is based the following description.

The only rocks known in the area to be visited are those of the Keewatin, Laurentian, Steeprock, and Seine series. The position of the Steeprock series, well down in the Pre-Cambrian, is of interest for the reason that the limestone of which it is chiefly composed, is fossiliferous.

Keewatin.—This is the oldest group in the region and consists chiefly of felsites (quartz porphyries), gabbros, diabases, greenstones, and their schistose equivalents, as well as occasional exposures of tuffs and agglomerate schists. The strike of the schistosity varies from place to place, but seems in a general way to accord with the contour of the lake shore.

Laurentian.—This is primarily a medium-grained hornblende granite gneiss, showing only a slight foliation in the Steeprock area. Near its contacts with the Keewatin, it not only holds as inclusions large fragments of the older series, but itself becomes quite basic, and grades into a type closely resembling typical Keewatin hornblende schist. In places, however, very sharp contacts of the two series in their normal phases are exposed. On account of its somewhat bleached appearance, and of its association with much sheared varieties in neighbouring localities, the series is correlated with the Laurentian.

Steeprock Series.—The rocks thus designated include the following formations in descending order:

4. Green schists, evidently of detrital origin, traversed by dykes and flows of diabase and diorite.

3. Volcanic ash, highly pyritiferous, schistose rock, often containing fragments of limestone and black cherty material.

2. Limestone, dolomitic to sideritic, and usually weathering brown. The exposures at the sharp bends in the shore-line of the lake are a brecciated variety, consisting of angular fragments of limestone, black chert, and typical Keewatin rocks.

1. Basal conglomerate, usually fine-grained, and frequently of the nature of a quartzite or arkose.

The rocks of the series are almost in a vertical attitude, the prevailing dips being 70° to 90° S.W. The series is tentatively correlated with the Lower Huronian.

Seine Series.—Quartzites and quartzose slates of the normal type, striking almost east and west, occur some

distance south of the lake, and along the Canadan Northern Railway line in the vicinity of Atikokan.

Structure of the Area.—A good partial cross-section of the Steeprock series is exposed along a line from the west side of Strawhat lake to the east side of East bay. In this section, a twofold repetition of the same set of beds in reverse order is evident. The general strike is N.W.-S.E. On the east, the conglomerate is in visible contact with the Laurentian, while on the west it rests on the Keewatin basement. The structure which has been worked out for the area by Dr. Lawson is that of a simple, closely folded syncline, whose axis is parallel to East bay, and whose trough covers the contact of the Laurentian and Keewatin.

In contrast with the folded condition of the Steeprock series is the uniform monoclinal attitude of the Seine quartzites and quartz slates. This stratigraphical and structural relationship indicates that the folding, which involved the Steeprock series as a sharp trough sunk down into the older Archæan, had taken place anterior to the deposition of the Seine series. It is therefore inferred tentatively that the Steeprock series is older than the Seine series.

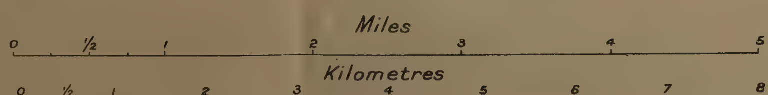
The distribution of the Steeprock series and of its limestone and basal conglomerate members, as far as they have yet been differentiated from the Keewatin, is shown on the accompanying map. The exposures in the southwest corner on Seine river are a brownish calcareous schist, not unlike that on the south shore of Falls bay. They are, however, very closely associated with Keewatin felsites, and may be either Keewatin in age or infolds of the Steeprock limestone.

The areal geology, indicated on the map, is only approximate, as detailed surveys have not yet been made.

Progress of Exploration. The geology of the area, on account of the features of especial interest which it presents, has received considerable attention from the Geological Survey of Canada and other sources. In 1891, H. L. Smyth (**10**) published an interesting set of results obtained from an examination of the area. W. McInnes and the late W. H. C. Smith (**4**) of the Survey mapped the region as part of the Seine River sheet in 1897. Dr. A. P. Coleman visited the area and published an interesting account of the geology in 1898 (**2**). In 1911, Dr. Lawson spent some time

Geological Survey, Canada.

Steeprock Lake, Rainy River District



in the neighbourhood, and in his report are embodied the results of the most recent work.

PARTICULAR DESCRIPTION OF POINTS TO BE VISITED.

Leaving the train at the station, a path is followed for 2·6 miles (4·2 km.) to Steeprock lake. At three-fifths of a mile (1 km.) from the station the first rock exposures are seen. They consist chiefly of Keewatin felsites, quartz-porphyries, and their derived schists, with which are associated, however, small lenses of a quartz conglomerate which may be infolds of the base of the Seine series. Exposures continue for about a mile (1·6 km.) farther, and are mostly of Keewatin acidic and basic types, although occasional small outcrops have a remarkably sedimentary aspect.

After embarking in the boats a straight course is taken to Jackpine point. On the left-hand shore are hills of Laurentian granite gneiss, while on the right Keewatin felsites and felsite schists, cut by dykes of post-Keewatin diabase, are exposed to view. At the north end of Falls bay a high brown bluff, consisting chiefly of the brecciated phase of the Steeprock limestone, stands out bcldly. Just as Jackpine point is reached a glimpse of Steep falls to the northeast may be obtained.

Cross-section of the Keewatin and Steeprock Series on the South Shore of Falls Bay.—In walking over this section from west to east, the Keewatin rocks are first noticed on Jackpine point where a schistose pyroclastic is splendidly exposed. The fragments are of the same material as the matrix, and although elongated in the general direction of the cleavage are not schistose like it. East of this are exposures of typical hornblende, chlorite, and felsite schists.

The basal conglomerate of the Steeprock series is well exposed next on a glaciated surface which extends for 150 feet (46 m.) across the strike (N 40° W). It should be noted that the pebbles are chiefly quartz and granite, with a few smaller ones of Keewatin diabase and greenstone. To the east of this is a brown calcareous schist with lenses, at times a foot (0·32 m.) thick, of ferruginous limestone. This is all of the western limb of the Steeprock limestone that is exposed on the south shore, but it is believed that

more of the formation and also a bed of volcanic ash occupy the depression in which the creek flows.

East of the creek are green schists of detrital origin traversed by sheet-like masses of diabase and diorite, which may be dykes or flows and which are younger than the Steeprock series. With these intrusions there seems to be associated diabase dykes which cut the granite and greenstone in such a way that they apparently represent the orifices through which the larger masses found their way to their present position.

Fossiliferous Limestone at Point No. 1.—By crossing in an easterly direction to a steep brown bluff, the first exposure of the limestone in the eastern limb of the syncline may be examined. The contact with the older rocks is not exposed here, but lies under the drift in the depression just to the east. An example, on a small scale, of the deformation which the formation once suffered, may be seen at the western corner of the point. The original bedding and joint-planes of the limestone are rendered visible by the abundant development of lime-silicate minerals along them, which have weathered into relief. A small exposure of a calcareous green schist probably developed from the limestone may be seen also at this point. The attitude of the beds should be observed.

The fossils are located chiefly at the southern corner of the bluff, and are quite abundant, especially near the waters edge. *Atikokana lawsoni* (**15**) seems to be the main species represented at this point. It is one of a group of organisims related to the sponges. Both silicated and calcareous varieties occur.

From Point 1 a southeasterly course is taken to Point No. 2, about half a mile (0·8 km.) distant. Along the route bold Laurentian hills easily distinguishable by their pale pink weathering, may be seen to the east. Dark-coloured patches occur scattered here and there through the gneiss. In some cases there are dykes similar to those associated with the crystalline traps of the Steeprock series, while in other cases there are detached masses of the intruded Keewatin engulfed by the granite when still in a viscous condition. The Laurentian-Keewatin contact zone is approximately in the trough occupied by the lake. A narrow fringe of limestone which may be distinguished by its brown colour, extends almost continuously along the east shore between the two points.

On the west side of the bay, the geology is quite different. The high ridge which roughly parallels the bay consists chiefly of the crystalline traps (diabase and diorite) and associated clastic green schists of the Steeprock series. Along the waters edge, directly west from Point No. 2, is a small exposure of the volcanic ash of the same series.

Fossilferous Limestone and Unconformable Contact of the Steeprock Series with Laurentian at Point No. 2.—At this locality, the attitude of the limestone beds is well marked, and may be best seen in the bay at the south end of the bluff. From this bay a trail leads a short distance up the hill over granite, and then swings northwestward across the unconformity. A continuous section at right angles to the contact is exposed. The granite may be followed westward from a comparatively unaltered phase through 45 feet (13·7 m.) of a schistose, gritty, bleached variety to the Steeprock series basal conglomerate. The transition is not a sharp one. The conglomerate, which contains small pebbles, chiefly of quartz and fine-grained granite, is from 5 to 8 inches (12·7 to 20·3 cm.) thick and is followed in the direction of the limestone by 50 feet (15·2 m.) of thinly bedded impure, quartzitic and slaty rocks. The limestone is in sharp contact with these. The nature of the unconformity should be carefully noted in order that it may be compared with that between the Laurentian and Seine series to be seen on the Mine Centre trip.

Fossils are best seen on the face of the bluff near the waters edge.

Fossiliferous Limestone at Trueman Point.—From Point No. 2 the course is a direct southeasterly one up the bay, with exposures of the basement complex on the east and of the Steeprock series on the west.

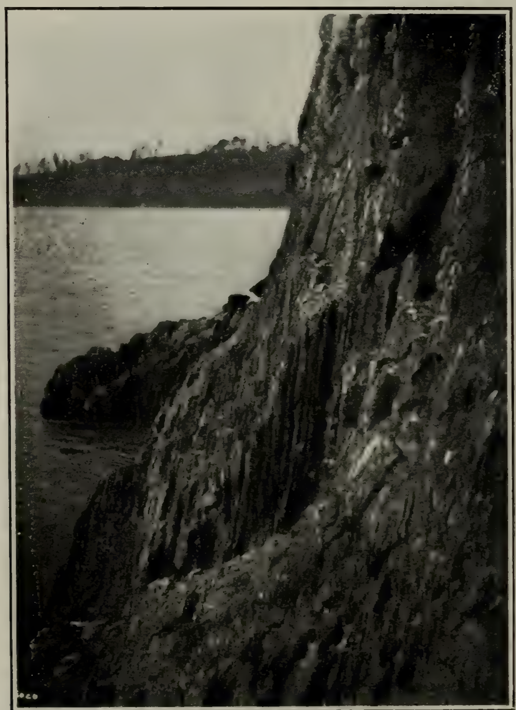
A ledge on the eastern side of Trueman point, near the narrow rock joining it with the main shore is the locus of Dr. Lawson's original discovery of fossils. Two varieties are to be found. They are quite abundant near the waters edge, especially along the face of the bluff.

The contact of the limestone with the older rocks is not exposed, but the fragmental formation between the limestone and the granite gneiss may be seen on the side of the hill just east of the southern landing.

In places the limestone is quite sideritic, and appears as a thinly-banded, brown and grey rock, resembling a

lean phase of the iron formation. This variety is exposed near the centre of the west face of the bluff, where there is a slide of talus material.

The attitude of the beds is well shown near the waters edge, where there is an abundant development of the lime silicates, which have weathered into marked relief.



Fossiliferous Steeprock limestone, Trueman point, Steeprock lake, Ontario.

A dyke of quite unaltered diabase cuts the Laurentian about 500 feet (152 m.) north of the northern landing, and probably represents a vent through which some part of the sills or flows in the Steeprock series reached their present position. Numerous basic, dyke-like masses cut the granite in this neighbourhood.

Brecciated Limestone at Elbow Point.—From Trueman point a direct return trip is made to the northwest end of Elbow point, where a breccia made up of angular fragments of limestone, black chert, and Keewatin felsite and greenstone, cemented together by crystalline limestone is well exposed. Interbedded with this are layers of a more or less pure limestone. As pointed out above, these brecciated phases are chiefly exposed at the sharp bends in the shore-line.

After examining this locality, the return journey is made to Atikokan.

ANNOTATED GUIDE.

(Atikokan to Mine Centre).

Miles and kilometres.

Beyond Atikokan the railway proceeds in a general way down the valleys of the Atikokan and Seine rivers for 35 miles (56·4 km.). The Seine series-Keewatin unconformity, with the younger series on the south side, follows with minor irregularities the bed of Seine river almost as far west as Mayflower. Occasional exposures of the Seine series are seen along the railway, except in two small stretches from mile posts 147 to 149, and from 159 to 161, where the contact swings south of the railway, and parts of the Keewatin belt are crossed.

160·0 m. 257·8 km. **Banning**—Altitude 1,256 ft. (383 m.). In this vicinity, diamond-drilling for iron ores has been carried on recently, but the results have not been highly satisfactory. The outcrops, which are of a hard iron formation in association with Keewatin greenstones, lie close to the railway and constitute probably part of the western extension of the Atikokan iron range.

After passing mile post 161, splendid exposures of the Seine schists and slates may be seen in the cuts on both sides of the railway as far west as Mayflower.

164·7 m. 264·9 km. At this point a stop of about fifteen minutes is made to examine a case of post-glacial faulting (8) in the Seine series. The exposure is just

Miles and Kilometres.

a few feet south of the track, and the chief points to be noted are:—

1. The nature of the rocks—phyllitic slates.

2. The strike and dip of the bedding or cleavage planes.

3. The reverse or overthrust character of all the faults.

4. The constancy of direction of the glacial striae, and their extension on both the upthrow and downthrow sides to the very edge of the fault plane.

5. The sharpness of the fault scarps.

6. The coincidence of the fault-planes with the cleavage of the slates.

7. The absence of fault breccia or slickensides.

8. The absence of any horizontal component in the differential movement.

9. The number of fault scarps (24 in 66 feet (20 m.) across the strike), and their average height.

10. The presence of a transverse fault.

11. The presence of one stepped scarp.

For reasons explained in his paper (**8**) Dr Lawson ascribes the faulting not to orogenic forces, but rather to the play of compressional and relaxational forces resulting from change of temperature or load. He cites other examples from geological literature of such faulting, and concludes that it is peculiar to slaty rocks.

165·0 m. 265 km. **Mayflower.**—From a short distance west of Mayflower to milepost 169, the Seine-Keewatin unconformity is again south of the railway, and Keewatin rocks are exposed on both sides. For the succeeding eight miles (12·8 km.) the railway runs in a northwesterly direction and affords a partial section of the Seine series, through the quartzites and slates to the basal conglomerate, which is excellently exposed just west of Mathien. (176 m., 283 km.)

The remainder of the trip as far as Mine Centre is through a drift-covered area underlain by the Keewatin which outcrops only at intervals.

Miles and Kilometres.

190·5 m. 306·5 km. **Mine Centre.**—Altitude 1,190 ft. (363 m.) From this point a trip is taken to the site of the Golden Star mine on Bad Vermilion lake to examine the following points: an occurrence of limestone in the Keewatin series; the contacts of the Seine series with the Keewatin, of the Seine series with the Laurentian, of the Laurentian with the Keewatin, and of the anorthosite gabbro with the Keewatin; and the lithological characteristics of the rocks of the various series.

GEOLOGY OF THE VICINITY OF MINE CENTRE.

GENERAL DESCRIPTION.

The area to be visited has the typical physiography of the southern part of the Pre-Cambrain terrane, and is not essentially different from that of the Steeprock lake area. Bad Vermilion lake is six miles (9·6 km.) long in a direction a few degrees south of west, and follows in a general way the strike of the Keewatin schists. It contains comparatively clear water, and has depths of 400 feet (122 m.) and over in places. The bold, glaciated rocks on the southern shores stand out prominently.

The general geology of the area is identical with that of a great part of the region just passed through. The particular interest attached to this locality is due to the remarkably well exposed contacts which lie within 500 feet (152 m.) of the old mine. The geological succession, in descending order, is:—

Archaean......
- Seine series.
    - *Unconformity.*
- Laurentian.
    - *Irruptive contact.*
- Anorthosite (Keewatin?).
    - *Irruptive contact.*
- Keewatin.

Keewatin.—Typical rocks of this series are well exposed in the area, and consist of greenstone, green schist, diabase,

agglomerate schist, felsite, felsite schist and a limestone and chert formation.

Anorthosite.—This is a highly feldspathic saussuritized gabbro or anorthosite which is areally disposed like a collar about a central heart-shaped boss of granite. It is clearly intrusive into the Keewatin, presumably in the form of laccolithic lens which tapers westward. The intrusion took place probably before the severe deformation of the Keewatin, for the gabbro is itself intensely sheared locally. The rock contains in places crystals of anorthite 10 inches (25 cm.) in diameter.

Laurentian.—This consists of a medium to coarse-grained, light-coloured, biotite granite, locally poor in biotite, and thereby grading into alaskite. It is intrusive into the anorthosite, as well as into the Keewatin, and it is believed, from the areal relations of the rocks, that it attained its present position by arching up the lenticular anorthosite sheet.

Seine Series.—Within the area under discussion the Seine series is represented chiefly by a great thickness of basal conglomerate which grades upward into typical quartzites and slaty schists. The conglomerate contains a large amount of debris derived from the waste of Keewatin rocks, but the pebbles and boulders, which are usually well water-worn, consist chiefly of different varieties of granite with a subordinate proportion of greenstone, quartz porphyry and dark coloured chert pebbles.

Particular Description of Points to be Visited.

The Keewatin Series seen en route to the Mine.—A trail about half a mile (0·8 km.) long leads from Mine Centre station southwest to the shore of Bad Vermilion lake. Two ridges of Keewatin rocks are crossed by this trail. One, just south of the village, consists of highly schistose felsites and quartz porphyries, while the other, which borders the north shore of the lake, is made up of quite basic rocks, which are greatly deformed, owing, no doubt, to their proximity to an area of intrusion.

The lake is crossed in boats to the road leading to the burnt remains of the Golden Star mine. Here Keewatin greenstones and felsites are exposed on all sides.

A trail, leading directly south across the hill, is followed for about 300 feet (91.4m) to where it joins the mine road.

On top of the hill may be seen excellent exposures of the Keewatin, consisting of calcareous schists with lenses of ferruginous limestone, and a band of schistose volcanic agglomerate. The road eventually leads to a well, which is the starting-point for the first side trip.

Limestone Bands in the Keewatin.—From the well, a path 500 feet (152 m) long, marked by yellow flags, leads to an exposure of Keewatin limestone. On the right hand side of this path, before coming to the limestone may be observed ridges of grey-green weathered felsite, much fractured as a result of igneous intrusion.

The limestone occurs in a series of bands from a few inches to a foot thick, which are interlaminated with discontinuous bands of chert and chert agglomerate. The total width of the formation is about 10 feet (3.2 m), and it can be traced along the strike for 275 feet (84 m). The strike is N 65° E, and the dip 50° to 60° N. W. The limestone is a highly granular, medium-grained variety, containing an abundance of minute crystals of brown mica scattered through its mass. An analysis shows that it contains only 0.35 per cent $MgCO_3$. Resting upon the limestone is a two foot (0.61 m) bed of brecciated chert, which grades upward into a porpyhritic dense felsitic lava. The proof of the contemporaneity of the limestone and the felsite is important in discussing the relation of the limestone to the Seine series.

Unconformable Contact of the Seine Series with Keewatin Felsite.—The mine road (marked by white flags) is next followed in a southeasterly direction for 200 yards (183 m), up a hill of felsite cut by basic igneous dykes. The ruins of the mine, which was destroyed by the Rainy Lake fire of three years ago, may be seen on the right. A path marked by blue flags, leading to the left is then taken. It affords an opportunity of observing the contour of the felsite, and leads to the contact of the felsite with the Seine series near the top of the ridge. The character of the felsite should be noted in order that the pebbles in the conglomerate may be compared with it, and the contact, which is located by red flags, should be followed a short distance to observe the nature of the basal conglomerate.

Irruptive Contact of the Laurentian with the Keewatin.—The white flag route is followed for a short distance to where it is joined by another road from the west. At this point, a series of green flags marks

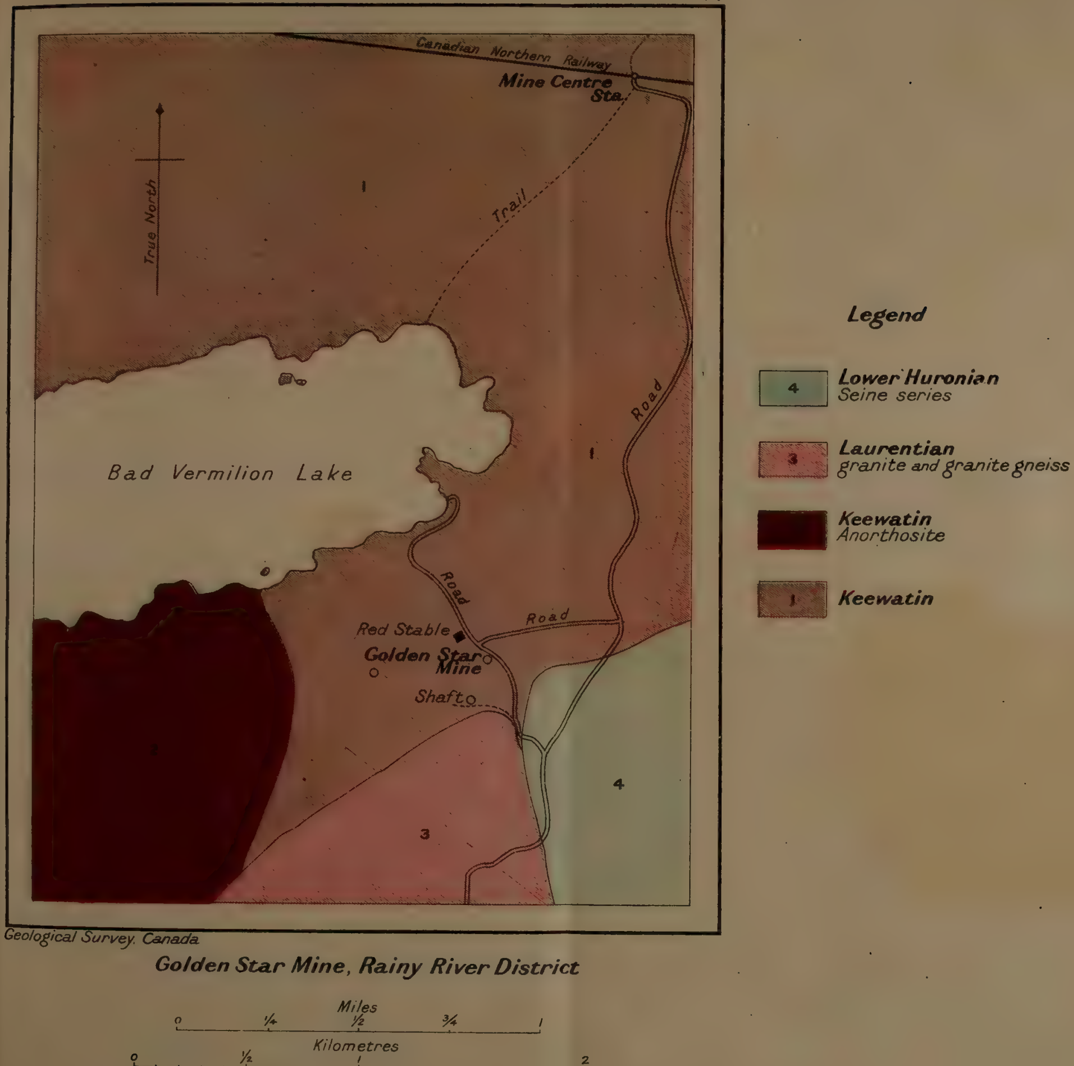
the Laurentian Keewatin contract. The exposures are not good, but the two formations may be observed within five feet (1.5 m) of each other, and fine-grained dykes may be seen traversing the felsite. Near the contact the granite is characterized by a comparatively fine-grained texture. On the main road from Mine Centre to Shoal lake, the granite holds angular inclusions of the nearby Keewatin rocks.

Unconformable Superposition of the Seine Series upon the Laurentian.—A few yards farther along the white flag route, the contact of the Seine and older rocks crosses the road. To the right (southeast) the contact of the basal conglomerate with the granite is marked by brown flags. The lower 15 feet (4.6 m) of the conglomerate is composed of a yellowish grit, or arkose, formed by the disintegration and re-cementing of the granite. The two rocks are notably similar. At a short distance from the contact the granite assumes its normal pale pink colour and granitic texture. By walking 200 feet (61m) southeast along the unconformity the relations and characters of the two formations may be observed more fully.

A few quotations from Dr. Lawson's report (**6**) will serve to draw attention to some of the salient features:—

"The bottom portion of the conglomerate formation, while very clearly detrital, is neither water-worn nor far transported. The fragments which compose it are regular detritus of a desert alluvial slope. Where it rests upon the granite, the detritus is nearly all derived from the underlying granite, blocks of granite being enclosed in a coarse quartzitic arkose matrix; and where it rests upon the nearby Keewatin, it is nearly all derived from the underlying rocks of that series, but with considerable quartz in some parts of the matrix. This facies of the accumulation is very evidently the same as that described elsewhere under the name of fanglomerate.

"Since the fanglomerate is without doubt a subaerial formation it grades up into a conglomerate in which the boulders and pebbles are well water-worn, it seems a fair inference that the conglomerate represents a gravelly flood-plain rather than the beach of a trangressing sea. If this be true, then in a general way the distribution of the conglomerate as outlined on a general geological map of the region indicates the course of a river."



Golden Star Mine, Rainy River District

This unconformity should be compared with the Laurentian-Steeprock contact visited at point No. 2.

The Anorthosite and its contact with the Keewatin.—This contact is exposed on the south shore of Bad Vermilion lake about half a mile (0·8 km.) west of the Golden Star mill.

Dykes of anorthosite may be seen cutting the Keewatin and small areas of the coarse-grained variety are exposed near the end of the trail which leads to the top of the ridge.

The Golden Star Mine.—The Golden Star mine resulted from a prospectors' "rush" in Rainy Lake district eighteen years ago. A well-equipped surface plant was installed and underground workings totalling 3,500 feet (1,065 m.) were carried to a depth of 537 feet (163 m.). The ore body, which was a quartz vein associated with aplite dykes, carried values chiefly in gold, with small amounts in silver and copper. The gangue was principally aplite and ferrodolomite. All operations ceased thirteen years ago (1900) and the plant was burnt in 1910 (**16**).

ANNOTATED GUIDE.

(Mine Centre to Bear's Pass.)

Miles and Kilometres.

After leaving Mine Centre, the railway follows the south shore of Turtle lake, and proceeds almost due west for about 12 miles (19·3 km.). The country is flat and, to a large extent, swampy. Occasional exposures of Keewatin rocks, greenstone, diabase, and green schist, may be seen. A short distance north of milepost 195 is the location of the Olive gold mine, a glimpse of which may be caught from the train. The mine is an old one, having been opened up at the time of the Rainy Lake gold rush, but is at present inactive. A drift-covered area of Keewatin rocks extends to about mileage 200·5 (323 km.).

200·00 m. **Farrington**—Altitude 1,154 ft. (352 m.).
322·0 km. In this neighbourhood rock exposures are rare. Hills of the basement complex may be seen here

Miles and Kilometres.

and there in the distance. Half a mile (0·8 km.) west of Farrington an area of Algoman biotite granite gneiss, which continues to Bear's Pass, is entered. The country underlain by this formation is generally more rugged than the previous 20 miles (32 km). A short distance west of milepost 207, Keewatin rocks are again seen, but the contact with the granite gneiss is not visible in the immediate vicinity of the railway.

207·3 m. 333·8 km. **Bear's Pass**—Altitude 1,143 ft. (349 m.). From this point a trip five hours in length is taken in boats around the shores of the eastern arm of Rainy lake for the purpose of examining the Coutchiching series, and observing its relations to the Keewatin and the Algoman granite and syenites.

THE COUTCHICHING SERIES ON RAINY LAKE

General Description.

The Rainy Lake area affords a typical example of the rocky lake topography of the Pre-Cambrian shield. It is part of that region investigated by Dr. Lawson in 1885–1888 (**5**). The geology of this area was revised by the same investigator in 1911, certain important changes in correlation being rendered possible by the improved accessibility of the country and by the more advanced state of knowledge regarding Lake Superior geology in general. The following descriptions and review of the geology are based on the results of his recent work (1911) (**6**). The geological sequence of the rocks exposed is given below in descending order:

Archæan	Algoman	
	—*Irruptive contact*—	
	Hornblende gabbro (Keewatin ?)	
	—*Irruptive contact*—	
	Keewatin	Ontarian
	Coutchiching	

Coutchiching.—This group of rocks consists of mica schists, feldspathic mica schists, and evenly-laminated,

fine-grained gneisses. Their character throughout the area is remarkably uniform. They are believed to represent in a highly anamorphosed condition the old sedimentary crust through which the Keewatin igneous rocks were erupted and poured out as flows.

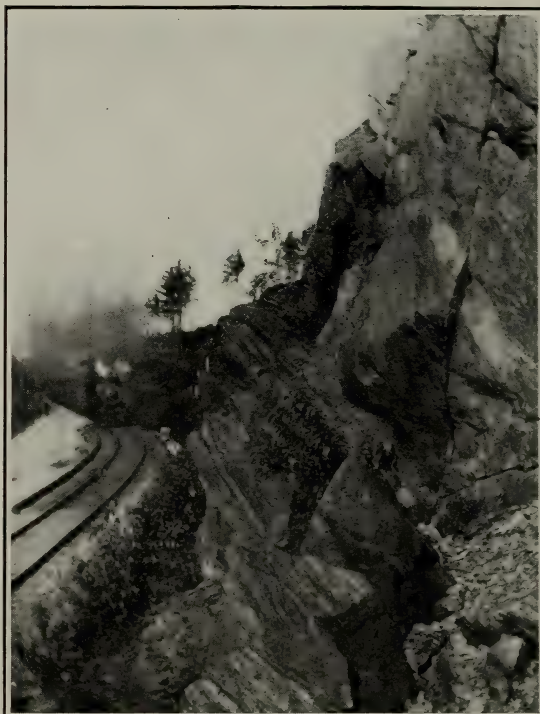
Keewatin.—The basic types, gabbro, diabase, diorite, basalt, tuff, and their schistose equivalents predominate in this district. They are metamorphosed to variable degrees, some of the gabbros and diorites being quite unaltered.

Hornblende Gabbro.—Thick sill-like masses of a rather schistose gabbro occur in association with the Keewatin series. The predominant femic mineral is hornblende, but large idiomorphic crystals of basic feldspar are abundant. Contacts with the Keewatin are exposed at a number of localities, where the gabbro is seen to be clearly intrusive into the Keewatin. The fact that it is wholly confined to the Keewatin area suggests that the intrusion is a sill or sills injected into the Keewatin prior to its deformation and metamorphism.

Algoman.—This group consists of medium-grained biotite granite and granite gneiss, with less important areas of mica syenite, and mica syenite gneiss, which have in this district developed a remarkably basic facies. On account of the warm flesh to pink colour of the granite, of the fresh biotite it contains and of the marked contrast in the general appearance of the rock, with the highly sheared Laurentian granites of Rice bay and other localities, Dr. Lawson identifies this group with the Algoman.

Structure of the Area.—The stratigraphical relations of the Coutchiching, Keewatin and Algoman groups are well exposed on the shores of the lake, and may be seen at different points along the route. An examination of the strikes and dips of the Coutchiching as platted at different points on the map shows that the formation is in the shape of a large symmetrical anticline with the axis striking N.E.-S.W. Locally around bosses of granite, the anticline approaches a dome in form, with the planes of the Coutchiching dipping on all sides away from the granite. The gradual passage of nearly flat-lying beds along the anticlinal axis to more steeply dipping ones vanishing under the Keewatin belts on the east and west shores, may be easily traced. No unconformity, other than an abrupt transition from the distinctly igneous rocks of the Keewatin

to the uniformly micaceous gneisses and schists of the Coutchiching, is present at these points. The transition marks a decided change in the conditions of rock formation.



Coutchiching mica schists dipping beneath Keewatin greenstone, Rainy lake, Ontario.

The irruptive nature of the Algoman-Coutchiching contact may be observed at several points to be visited. In proximity to the contact, inclusions of previously schistose Coutchiching are surrounded by the biotite granite, while apophyses of the granite invade areas of Coutchiching. In such localities, certain beds of the Coutchiching are abundantly supplied with secondary aluminous silicates.

It is interesting to note that the figures which represent the dips of the bedding planes away from the granite

bosses agree with the attitude of the contact plane between the granite and the Coutchiching schists, this contact being exposed in the face of cliffs that have various salients and re-entrants. The anticlinal form of the mica gneisses and schists is due to the intrusion of the Algoman batholith which has simply arched them over itself to form a roof. Dr. Lawson's conclusion is stated thus: "The Coutchiching rocks are disposed in an anticline domed around an intrusive mass of granite, and they pass on both flanks of the anticline beneath the Keewatin".

PARTICULAR DESCRIPTION OF POINTS TO BE VISITED.

After leaving the train at Bear's Pass the route around the shores of the lake follows in numerical order the small numbers, 1 to 32 on the map.

From the station to 1, a partial cross-section of the Keewatin, is exposed. The strike and dip of the schist and the nature of the coarse-grained gabbro can be observed Going southward along the shore between 1 and 2, the transition from Keewatin hornblendic and chloritic rocks to Coutchiching micaceous schists, with about the same strike and dip, may be seen, the latter dipping beneath the former. From 2 to 4 the irruptive contact of the Algoman biotite granite and the Coutchiching is well exposed; the long narrow point at 3 affords a splendid view of the contact breccia. The granite is pale pink to white in colour, and somewhat fine-grained. The shore line in this vicinity shows alternate outcrops of Algoman and Coutchiching.

A landing is made at 4 to examine the contact between the Coutchiching and the Keewatin. Here the micaceous schists are markedly quartzitic and are beautifully plicated. The contact with the rather massive Keewatin greenstone is sharp, and the Coutchiching dips rather steeply under it.

From this point in a westerly direction to 8 an excellent section is obtained across the Coutchiching formation almost at right angles to the anticlinal axis. The shore is followed closely, so that the attitude of the Coutchiching beds may be noted. The steep southeasterly dips of the formation to the east gradually flatten, until in the neighbourhood of 5 and 6 they are nearly horizontal or locally buckled. Here the locus of the anticlinal axis is reached.

From 5 west, the dip is in the opposite direction, that is, to the northwest, and gradually increases to 45° or 50° The steep dips of 60° to 75° on the eastern limb of the anticline are nowhere seen on the western limb. Along the shore near 7, the nature of the formation at a distance from the intrusive granite and the attitude of the beds are exposed to advantage.

From 8 to 9 the contact between the Coutchiching and the Keewatin can be traced approximately. On the left hand side the mica gneisses and schists, dipping from 25° to 45° towards the northwest, are well exposed. On the right, the islands numbered 26, 25 and 22 consist of typical Keewatin formations.

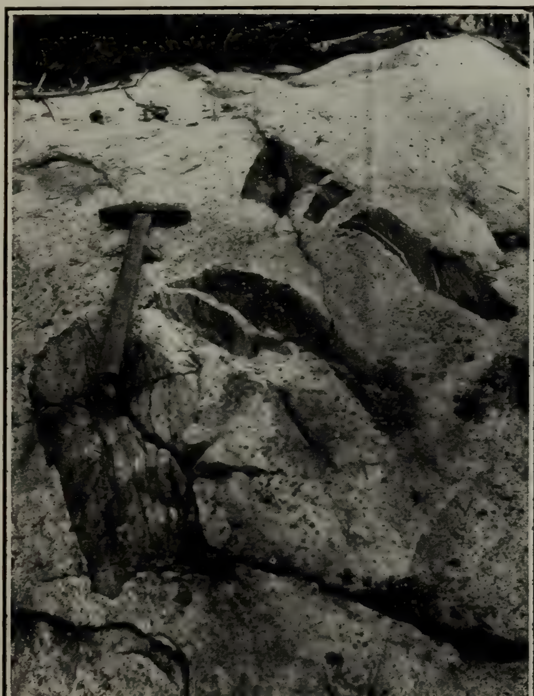
From 9 through Bear's Passage to 13, another section is made across the anticlinal axis of the Couchiching. Generally speaking, the dips change from northwest to southeast through an intermediate, approximately horizontal attitude. The intrusive granite, which is exposed in actual contact with the Coutchiching from 10 to 11 is a disturbing factor in this section. Near its margin, the mica gneisses and schists strike roughly parallel to the contact, and in all cases dip away from the granite boss, as if they had been arched over its surface at the time of the intrusion. A gradual increase in the angle of dip is observed from 12 to 13, until, at a maximum of about 70° to the south-east, the Coutchiching disappears under the more massive rocks of the Keewatin. The actual contact is not exposed here.

From 13 to 14 a belt of Keewatin schist with a steep southeasterly dip is crossed to another band of Coutchiching, also dipping steeply to the south east. This Keewatin belt is interpreted as the eroded remnant of an appressed synclinal trough, overturned towards the southeast, and pitching to the northeast. In this second or Shelter Cove belt of Coutchiching, the series is represented by quartz slates rather than the metamorphic mica schists. At 15 a good exposure of the Coutchiching in an almost vertical attitude may be seen. Farther east, it passes again under the Keewatin.

The course now leads directly to Bear's Passage and along the left hand shore from 16 in a northwesterly direction. An almost continuous outcrop of Algoman granite with large inclusions of mica schist follows the shore to beyond 17, and may be observed in passing.

The granite-Coutchiching contact is crossed between 17 and 18. At the latter point, there is a good exposure of a basic facies of the Algoman syenite intruding the Coutchiching, which dips away from it on all sides. The contacts are well exposed.

The shore line is closely followed to the railway crossing, and typical exposures of Coutchiching, abundantly supplied with secondary crystals of the aluminous



Inclusions of Coutchiching mica schist in Algoman granite, Rainy lake, Ontario.

silicates may be seen from 19 to 20. At 20 the mica schists clearly dip under the Keewatin. At 21 is a small exposure of a conglomerate-like rock associated with the Keewatin.

The island at 22 consists of Coutchiching garnetiferous schists dipping at 20° to the northwest. By landing at the north end, an excellent opportunity is afforded to observe their attitude with respect to the Keewatin group which underlies the island (23) immediately to the north.

From 24 to 27 are exposures of a hornblende gabbro showing phenocrysts of basic feldspar. The contacts of this formation with the Keewatin are not conveniently exposed on the shores of the lake.

From here, the shore line is followed rather closely in a northerly direction to 30. Apart from small areas of Coutchiching at 28 and 29, the exposures consist chiefly of Keewatin medium-grained, massive to schistose diorite. At 30 the Coutchiching schists again pass beneath these.

The lake is now crossed in an easterly direction to 31, where a landing is made to examine the excellent contact breccia of Coutchiching and Algoman there exposed. The inclusions of previously schistose Coutchiching enclosed in the invading granite, as well as the apophyses of the latter cutting the former may be noted. A small area of nearly flat-lying mica schist between 31 and 32 represents a remnant of the roof of the batholith. At 32 a striking exposure showing horizontal jointing in the granite may be seen from the boats. Just north of 1 another Keewatin-Coutchiching contact might be advantageously examined, after which a return is made to the station.

ANNOTATED GUIDE (Bear's Pass to Winnipeg).

Miles and Kilometres.

From Bear's Pass station the railway runs along the western edge of the Keewatin synclinal trough, described above, to 4, where it enters the Coutchiching and pursues a course across the latter nearly at right angles to the anticlinal axis. The more or less flat-lying Coutchiching beds in the cuts between mileposts 209 and 210, represent remnants of the batholith roof. After crossing the narrows northeast of Bear's Passage the railway passes again into Keewatin, intruded by hornblende gabbro. Leaving this, another Coutchiching belt is crossed between mileposts 212·5 (342· km.) and 214 (344·3 km.), beyond which the

Miles and Kilometres.

Keewatin again outcrops, and with intrusions of the gabbro continues to milepost 222. The gabbro-Coutchiching contact is followed somewhat closely to mile-post 224, where, near the westerly end of the Rainy Lake crossing, the railway passes into the Algoman granite.

After leaving the lake, the alluvial plain country is entered and only occasional outcrops are visible. The eastern boundary of the bed of glacial Lake Agassiz (**12**) has not been very accurately located, but it is believed to be near the eastern edge of Rainy lake. The lake deposits may be seen almost continuously to Winnipeg, although the sands and stratified gravels have been rearranged in places to form part of the alluvial plain of Rainy river.

231·3 m. 372·3 km. **Fort Frances.**—Altitude 113 ft. (340 m.). The bed-rock from Fort Frances westward to Winnipeg is almost unexposed. From the occasional outcrops that do occur, and from the small mining operations carried on in the region, it is believed that the country is under-

286 m. 460 km. lain (Rainy river) chiefly by rocks of Pre-Cambrian age, at least as far west as the Manitoba boundary The description by Dr. Lawson (**6**) of an exposure of possibly Richmond fossiliferous limestone (Ordovician) about six miles (9·6 km.) west of Fort Frances is interesting, as it may prove to be an outlier of the Palæozoic of Manitoba.

324 m. 521·4 km. **Warroad.**—At Beaudette the railway crosses the International Boundary line into United States territory, through which it runs for about 35 miles (56 km.), crossing back into Canada a few miles beyond Warroad.

439 m. 706 km. **Winnipeg.**—Altitude 760 ft. (231·6 m.).

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ORDOVICIAN AND SILURIAN OF STONY MOUNTAIN AND STONEWALL, MANITOBA.

BY

A. MacLean.

ORDOVICIAN—STONY MOUNTAIN.

The Teulon-Arborg branch of the Canadian Pacific Railway runs in a northwesterly direction from the city of Winnipeg 11 miles (17·7 km.) to Stony Mountain, and thence continues to Stonewall about 6 miles (9·6 km.) beyond.

On leaving Winnipeg, Stony Mountain may be seen rising apparently abruptly from the flat lacustral plain through which the train passes. The flatness of the country is emphasized when it is remembered that the "mountain" is 11 miles (17·7 km.) distant and rises only 50 feet (15·2 m.) above the surrounding country.

Between Winnipeg and the "mountain" no rocks outcrop and, save for the flatness of the lacustral plain, there are no features of physiographic or geological importance. The country is given over to mixed farming, and the production of dairy supplies for Winnipeg.

On approaching Stony Mountain, the hill is seen to the right of the railway. The west and north sides have abrupt faces, while on the south and east the hill slopes gradually away to the plain.

The Manitoba penitentiary stands on the brow of the hill nearest the railway station, while to the north and east of it are two quarries at present in operation. The magnesian limestones quarried here are of upper Ordovician age.

These quarries may be easily reached from the spur which leaves the railway about a mile north of the station and runs to the front of the quarries. In the quarry belonging to the city of Winnipeg is a good section which shows all the strata outcropping elsewhere over the mountain.

Though the beds are apparently flat, they have a slight dip to the southeast of 2 or 3 degrees. This attitude is in part responsible for the contour of the "mountain," with its sharp face toward the north and west, and gentle slope to the south and east. Glaciation has, however, accentuated this by developing a "crag and tail" topography by stripping the northern and western fronts and piling the debris thickly in the lee of the hills to the south and east.

On the top of the mountain glacial material is very scant, varying from a few inches to a few feet in depth. This rests on the upper limestone of the quarries, which, in most cases, shows scored and striated surfaces when freshly stripped. Below this a buff magnesian limestone is quarried for a depth of 12 or 14 feet (3·6 to 4·2 m.), when beds of yellowish brick-like shale are reached. These beds are 14 feet (4·2 m.) in thickness and rest on a reddish shale interlaminated with thin layers of limestone. The various beds exposed in the vicinity of the mountain comprise the "Stony Mountain" formation (**3**) which is composed of three main divisions: (**A**) an upper magnesian member about 12 feet thick in which the quarries are located and which contains a very meager fauna including several Beatriceas from the size of a cigar up to four inches in diameter and a foot in length, together with brachiopods and occasional corals; (**B**) a middle member about 15 feet thick consisting for the most part of a massive yellow brick-like shale which is almost filled in places with the casts and moulds of corals, bryozoans, brachiopods,

pelecypods, gastropods, cephalopods, and trilobites, a score or more of species having been identified; and (**C**) an exposed thickness of 12 feet of alternating thin limestone bands and red shale, the limestone layers bearing upon their weathered surface an even greater assemblage of fossils than were mentioned for the middle member, over fifty species having been identified, as follows: 5 corals, 1 crinoid, 17 bryozoans, 8 brachiopods, 8 gastropods, 3 cephalopods, 9 ostracods, and 3 trilobites. The interlaminated shale crumbles readily and specimens of corals, brachiopods, and bryozoans can be picked up from its weathered slopes. The detailed section of the beds in descending order is as follows:

	Mantle rock.—Glacial till, consisting of sand, gravel, and boulders, local and "foreign", with some clay and surface layer of soil.	2 inches to 5 feet, 5 to 15·2 cm.
A	1. Limestone.—Hard, white in colour, showing few or no fossils. In some places this has been stripped from the top of the quarry..	24 inches, 61 cm.
A	2. Limestone.—Hard, white in colour, breaks into 5 or 6 layers of irregular thickness. Surface may weather porous. Fossils not evident....................	14·5 inches, 37 cm.
A	3. Limestone.—Rusty, yellow, joint faces. No fossils...............	32 inches, 81 cm.
A	4. Limestone.—Compact, yellow, often shows coarse porous structure........................	40 inches, 102 cm.
A	*5. Limestone.—Yellow, with porous bands near top and bottom.	59 inches, 150 cm.

* Beds 2 to 5 constitute the quarries as they are usually worked. Fossils are not entirely absent, but the perfection with which the fossil is merged in the rock and the uniformity of both in texture and composition renders it difficult to detect them. In rare cases they are exposed by weathering in the quarries, the most striking of these fossils being the Beatriceas, which attain a diameter of four inches and a length of a foot or more.

B

6. Arenaceous shale.—Brick-like in texture, varies in colour from yellow to purple. Carries fossils of gastropods, brachiopods, corals, etc. . . . . 10 inches, 25 cm.

7. Calcareous shale. — Yellow, brick-like, showing in some localities fossils, generally as casts or moulds . . . . 60 inches, 152 cm.

8. Calcareous shale.—An irregular bed, weathering readily to a nodular mass, although in some places more compact. Few fossils . . . . 36 inches, 91 cm.

9. Calcareous shale.—Yellow, brick-like, very much like No. 7. Contains fossils, corals, bryozoans, brachiopods, gastropods, etc.,. . . 66 inches, 168 cm.

C

10 Shale.—Red, loose in texture, weathering readily to a crumbling mass. Interlaminated with limestone beds about 2 inches in thickness. Both limestone and shale are quite fossiliferous, bearing corals, bryozoa, brachiopods, gastropods, cephalopods, ostracods, and trilobites . . . . 144 inches, 366 cm.

The beds exposed in this section are believed to represent the Richmond and possibly the Lorraine formations of the Ohio Valley. Good sections of the lowest shale of the above section can be obtained in abundance.

This lowest shale is the best of the series for the collection of fossils, and is exposed at several places over the mountain. One of these is to the south of the Winnipeg city quarry, and just below the Manitoba quarry, near their old lime kiln. Two other exposures are on the prison reserve: one in the prison gravel pits in the face of the hill opposite the main buildings; the other a short distance to the southeast of this and in the same face of the same hill.

The shale above this (Nos. 7, 8, and 9 of the above section) is best exposed for collecting purposes in the cut on the east and west road to the north of the prison reserve, where 16 feet (4·8 m.) of thin bedded shaly limestone are exposed. Fossils occur here abundantly and include *Favosites aspera*, *Cyathophyllum* sp., *Platystrophia biforata* var. *lynx*, and *Rhynchotrema capax*. An occasional massive specimen of *Favosites aspera* may be seen in the basal beds of the quarry immediately north of the village. These sometimes have a diameter of 12 to 15 inches (30 to 38 cm.).

As already mentioned the beds which are quarried, yield but few fossils. Such as do occur may be best seen in some of the abandoned quarries, where weathering has assisted in bringing out an occasional one. Such a quarry is to be found directly east of the Manitoba Company's quarry, to the south of the road allowance which passes between the two quarries.

Beneath the light covering of till, the surface of thin limestone has been beautifully polished and striated in a direction S 20° E, furnishing evidence of the latest advance of the Keewatin glacier from the north and northwest. The Labradorian glacier from the northeast also reached this hill at a later period, but the striae left by it, being about southwest, are not abundant, as the older till protected the underlying rock. On the brow of the eastern side of the mountain, however, is a little ridge six feet (1·8 m.) high of angular blocks of limestone which may be a morainal accumulation shoved up by this glacier.

On the opposite side of the hill is an old gravel beach of Lake Agassiz, and in the head of the horseshoe-shaped summit is another lower beach.

SILURIAN—STONEWALL.

Between Stony Mountain and Stonewall there are no rock exposures along the line of railway. The country continues quite flat, but between the two stations there is a rise of about 50 feet (16·7 m.), Stony Mountain being 777 feet (235 m.) above sea level, and Stonewall being 826 feet (251·7 m.).

Just before entering Stonewall a test pit may be seen on the south side of the railway. On the north side, spurs lead to the quarries of the Manitoba Quarry Company.

Passing through the station, the track takes a semicircular course about the west side of the town, and turns in an easterly direction along the north side of the quarry operated by the Winnipeg Supply Company. In this quarry, the deepest cutting has been made and the best section is to be seen.

The strata are only exposed in the quarries, being elsewhere covered to a depth of 2 to 12 feet (.6 to 3.6 m.) Below this the surface of the rock is generally deeply scored,but in most cases the glacial polish has been removed, in all probability by the solvent action of surface waters. The rock is generally quarried to a depth of 12 or 14 feet (3.6 or 4.2 m.) below the topmost bed. When quarried it is used for crushed stone, rubble, and also for lime, for which it is eminently suited. The floor of the quarry is of red shale some 15 inches (38 cm.) in thickness, below which is six feet (1.8 m) of limestone in two beds. This is very hard, darker in colour than the limestone above, and is unsuitable for lime. Below this is a dark red shale which continues in depth below the level now exposed.

The section in descending order is as follows:—

A.	Soil and non-assorted material. Boulder clay or till of variable depth.		
	Stratified material.——Alternate layers of sand and shale, one inch to one quarter inch in thickness. Shale is well assorted. Sand layers are poorly assorted. No fossils......................	16 inches,	41 cm.
	Boulder clay or till, lying on surface of rock which is scored and striated........................	33 "	84 cm.

B.	Limestone, light colored and magnesian representing the uppermost course of quarry which in many cases has been removed...60 inches		152 cm.
	Limestone of the second course. Hard, massive, and very similar to the overlying bed from which it is distinguished only by difference in thickness. Both these courses contain a tabulate coral, generally poorly preserved except in one locality, to which reference will be made later........41	"	104 cm.
	Limestone. This is the lowest course generally quarried. Less massive than either of above, quite often breaking into laminae 2 to 10 inches (5 to 25c m.) in thickness.........................48	"	122 cm.

In one portion of this quarry operations were at one time continued below this, revealing the following:—

C.	Shale, red and nodular in character. The individual nodules are fairly hard, but the mass does not form a consistent bed..15 inches,		38 cm.
D	Limestone, yellowish in colour, hard and porous, probably magnesian. The pores are large, resulting probably from weathering out of fossils or other more soluble content. Tabulate corals and cephalopod remains occur in this layer...................31	"	79 cm.
	Limestone, similar to above, but lower half is darker in colour, and has much finer pores, uniformly distributed. Forms the "freestone" of this level............41	"	104 cm.

A test pit sunk at one corner of this part of the quarry shows other layers below this as follows:—

E.	Clay-like shale, fine grained, white in colour	6 inches,	15 cm.
	Bright red shale, breaking by irregular fracture to a mass of small angular particles. This bed is here exposed for 36 inches (91 cm.), and is reported to have a total thickness of	6 feet,	183 cm

Below this is said to lie seven feet (201 cm.) of freestone, but whether this is a hard porous dolomitic limestone or a true sandstone could not be determined. It is probably the former.

The strata at this place contain few fossils. The beds below those indicated "A" to "C' are exposed only in this quarry and contain few fossils. The fossils from the upper limestone occur in more abundance in an old quarry of the Manitoba Quarry Company, a little to the south and east of this one. In this place they occur quite freely in the walls, and in the rubble scattered over the floor of the quarry. Although the spicies are few, the specimens occur in large numbers and are well preserved. This quarry is reached by going east on Higgins street or Drake street, or by entering from the railway spur, previously mentioned, from the main line to the east of the station.

The most common species occurring here are *Favosites aspera*, *F. gothlandicus*, and *Plectambonites*?, sp. undet. Other species occurring here include *Aphyllostylus gracilis*, *Trimerella* sp. undet., *Dinobolus* cf. *conradi*, and several species of gastropods and cephalopods. The new cephalopod, *Sphyroceras meridionale* Whiteaves and *Cyrtoceras cuneatum* Whiteaves, and a new genus of corals *Aphyllostylus* have been described from material collected in the Stonewall quarries. (**4**).

The fauna is of Silurian age and is probably the equivalent of either the Guelph or Lockport. It represents a faunal province distinct from that of Ontario and Western New York, which makes precise corralation with the New York section impracticable.

The beds in the quarry walls appear horizontal, but those in the floor of the quarry show a distinct dip. In one case this is 2 or 3 degrees in a direction almost due south; in another case, one quarter mile distant, the dip is 2 or 3 degrees in a direction due west. The general dip over all the quarries is toward the southwest.

Grooves and striae trending S 20° E, made by the Keewatin glacier, may be seen on all fresh surfaces, while here and there some striae of the Labradorian glacier may be detected running N 80° W.

The presence of the stratified and partially assorted layer between the two boulder clays is indicative of a temporary recession of the ice, although the thinness of the layer and the absence of organic remains would suggest that it was probably local and of short duration.

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WINNIPEG TO BANKHEAD.

BY

D. B. Dowling.

INTRODUCTION.

THE GREAT PLAINS.

The central part of the continent to the east of the Rocky Mountains is generally referred to as the Great Plains. This name, as applied to the southern portion of the region, is descriptive mainly of its treeless character.

The topography of the plains, Winnipeg to Calgary.

It is however not without variety in its topography since a large part of it is a northeasterly sloping plateau of Mesozoic sediments etched into somewhat irregular surface contour, and overlapping a lower plain having the irregular features of the great pre-Cambrian shield.

In the belt traversed by the railway lines, a threefold division of prairie steppes rising one above the other to the west is clearly recognizable, though the term prairie may not be applicable farther north. These three divisions are here adopted for descriptive purposes and a fourth is added to include the broken, hilly country of the foothills.

The first and eastern division comprises the plain east of the Cretaceous deposits which rise as a low escarpment to form the plateau. The second extends from the edge of this plateau westward to the erosion remnants of former Tertiary deposits and the third from this line westward to the foothills.

First Division.—This division is the lowest in elevation and is essentially a region of lakes, with the exception that in the southern part the inequalities of the rock surface have been smoothed over by the deposition of clays and silts in glacial Lake Agassiz. This forms the rich farming country of southeastern Manitoba, where the extreme evenness of surface is noticeable because of the general absence of timber. This plain is however being partly forested by the individual efforts of the farmers.

The surface features east and north of Lake Winnipeg differ from those to the west in having the mammillated character typical of a region underlain by Pre-Cambrian rocks with but a thin mantle of drift. The large lake basins are due mainly to the removal of Palæozoic rocks from the older westerly dipping rock surface.

Traces of the margin of glacial Lake Agassiz remain in distinctly marked beaches resting on the slopes which rise upward to the Cretaceous plateau.

The railway ascends to the Cretaceous plateau up the wide delta and valley of the ancient Assiniboine river, where it entered Lake Agassiz. The present drainage of this region is northward to Hudson bay by Nelson river.

Second Division.—This division is the lower or eastern portion of the plateau and is underlain by a succession of shale beds and other equally soft rocks. The surface is about 1,000 feet (304 m.) above the Manitoba lakes or

1,800 feet (545 m.) above sea level, but is not a uniform plain. Several deep valleys traverse it, one of which was incised by the water of the South Saskatchewan river, at a time when the northward flow of that stream was blocked by glacial ice. This channel is now occupied by a small stream called Qu'Appelle river. Streams flowing eastward across the plateau have cut deep valleys into the escarpment which rises from the lower prairie level to the east and have left remnants standing as isolated hills which are known as the Pembina, Riding, Duck, and Porcupine mountains.

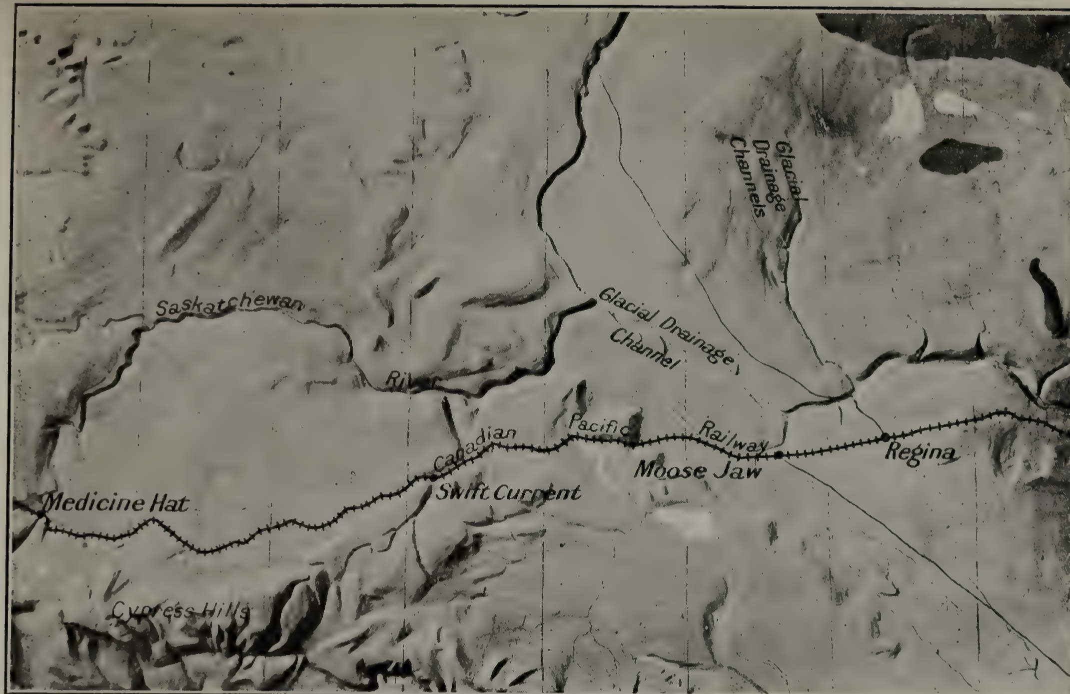
The drainage is eastward into a confluent series of streams entering the Assiniboine valley and northeastward into the Saskatchewan. Wooded areas occur in the north and along the outer edge of the plateau, while a few of the higher levels of the central surface are similarly covered.

Third Division.—This area, extending from the Coteau, or the hilly country just west of Moosejaw, to the foothills of the Rockies, is divided by the depression through which the South Saskatchewan river flows. To the north of this depression the drainage is mainly eastward to the North Saskatchewan, while the region to the south includes a fringe of the drainage basin of the Missouri river. There is also immediately west of the Coteau a small basin without outlet whose waters evaporate in Lakes Johnston and Chaplin.

The relief in this division is accentuated by the fact that much of it is bare of trees, so that such elevations as the flat topped Cypress Hills standing 2,000 feet (608 m.) above the railway near Medicine Hat or the Hand Hills 800 feet (243 m.) above the surrounding plains, become prominent topographical features.

Fourth Division.—The topographic character of the foothills is much more diverse than that of the other divisions. The geological structure is closely related to the topography, and all the hills are formed of folded or faulted rock masses.

Since the folding in these hills is due to the same causes that produced the Rocky mountains, the strike of the folds follow directions nearly parallel to the mountain chain. Although often of considerable elevation the summits of the foothills are not as serrated as the mountains, since the rocks composing them are of softer materials. Their flanks also are either grassed or clothed with



The eastern edge of the third Prairie Steppe and the Glacial drainage channels on the second Prairie Steppe.

timber. The general arrangement is a belt of varying width and elevation consisting of parallel ridges cut here and there by streams rising in the mountains behind.

ROCKY MOUNTAINS.

On the basis both of form and of structure the Rocky Mountain system is divisible into two parts:—a western, and an eastern part. The axial ranges constituting the western part have been carved from a slightly folded but greatly elevated block, the denudation of which was probably inaugurated before the eastern ranges were elevated. The eastern part is made up of monoclinal blocks, the beds of which they are composed being generally younger in age than those of the western part of the mountains.

Outer Ranges.—As topographic features these ranges are in a general way merely blocks more elevated than those of the foothills, from which nearly all the younger soft series of rocks have been removed, exposing the more consolidated Palaeozoic sediments beneath. The fault blocks are, as a rule, tilted westward, and along their eastern scarped faces remnants are often found of the anticlines which were broken near the crest, showing that these blocks were the western limbs of folds overturned and broken. The plane of the overthrust faults is frequently inclined at a comparatively low angle indicating that the thrust was from the west. The outer fault is often of this character, and the overthrust, although great in Montana, becomes modified in the Canadian ranges and decreases northward. In southern Alberta the Palaeozoic rocks of the watershed range on the British Columbia boundary line overlap the Cretaceous beds of the western part of the fault block, forming the Livingstone range; and Crowsnest mountain, which is an erosion remnant of Palaeozoic superposed upon Cretaceous rocks, stands as an example of this overthrust. The westward slopes of of these fault blocks depend to a great extent on the dip of the beds, so that a similarity in outline of their slopes is repeated along the range. The eastern slopes are often more abrupt, and their form depends largely on resistance of the strata to erosion or a disposition of fractures. Local glaciers have, moreover, etched this face into cirques and thereby contributed to the irregularity of the crest line.

The Western Rocky Mountains.—In contrast to the outer or eastern ranges, the mountains near the watershed stand in isolated peaks, carved from a large block of older rocks. Less folding and fewer faults occur. More massive bases and higher summits, to which cling many glaciers, give a more Alpine aspect to the scenery. Small cirques, such as the gap called White Man's pass at Canmore, in the outer mountains, give place in the inner ranges to great amphitheatres such as those in the vicinity of Laggan.

The first appearance of this part of the Rocky Mountain system may have occurred shortly after the Jurassic sediments were laid down, and then only as low ranges. Periods of subsidence and elevation may have followed and recurred throughout Cretaceous times.

HISTORICAL GEOLOGY.

The wide depression, in which the sediments of the central part of the continent were deposited, was at its greatest marginal extent probably in Devonian time. Earlier deposits appear on the southeastern margin and again in the mountains to the west.

A great series of ancient sediments, some probably Pre-Cambrian in age, is found in the area occupied by the western part of the Rocky mountains and the adjoining ranges to the west. This thick series shows in its upper part the existence of marine conditions during Cambrian time. The downwarp, which was here partly filled by coarse sediments, may not have extended far to the east from the continental margin of that time, and was probably separated from the main ocean by a barrier. A general subsidence before the close of the Cambrian is indicated by patches of rocks of this age on other parts of the continental area. Deep sea deposits, magnesian limestones of the Castle Mountain series, were formed before the recovery of elevation which closed the period.

Considering only the area east of the Rocky mountains, it is not clear, that during Ordovician time, the marine invasion shown by the character of the sediments at the top of the Castle Mountain series was other than by an arm of the Pacific. In the eastern part the invasion from the south in early Trenton time is marked by the deposition

of limestones in the Lake Winnipeg basin. A more general submergence during Devonian time is represented by beds of magnesian limestone which are exposed along the foot of the Cretaceous escarpment across Manitoba and in a broad sheet northward down the Mackenzie river and in the Rocky mountains throughout their entire length. The absence of the succeeding Carboniferous deposits in the eastern part of this basin, as well as to the north, suggests a retreat of the sea westward. In the mountain region Carboniferous limestones are prominent in southern Alberta, but northward these thin out and are replaced by sandstones and shales.

A farther retreat during Permian and Triassic time, during which sandy and shaly deposits were laid down, is indicated in a thin series of these rocks in the mountains. They extend northward to Stewart river in the Yukon, and prove that with the shallowing of the Carboniferous sea there was also transgression northward.

The crustal disturbances of Jurassic time in British Columbia were reflected in the inauguration of another downwarping movement that produced a narrow trough in the belt now occupied by the Rocky mountains. This permitted the entrance of the sea from the north across northern British Columbia. The deposits carried to this basin in general went to form fine grained black shales. Sandstone members appear in the lower part at intervals, but generally the source of the material is believed to have been at some distance. In northern British Columbia volcanic ash is intercalated with the sediments, and volcanic outflows are found on what were probably land areas.

At the close of the Jurassic, sedimentation became periodically rapid. Sands were washed into the basin and the surface elevation was maintained at or near sea level, so that the continental drainage replaced the saline water in the basin. Land areas were maintained for long periods during which coal seams were formed from the vegetation. This period, which is generally ascribed to the Lower Cretaceous, was closed by a general subsidence to the east, in which the sea advanced again to cover a large part of the centre of the continent. This invasion of the sea submerged the fresh water deposits of the Dakota in the east and also spread in the central part of the basin similiar sandy beds as basal members of the marine series.

In the west the marginal beds below the marine Cretaceous sediments are as a rule fresh water deposits. The coarse conglomerates and sandstones, there found belonging to this period of extension of the Cretaceous sea, indicate some corresponding uplift in the land area to the west which increased the gradient of the slopes. The coarseness and thickness of the material contained in these beds (maximum 6000 feet, 1824 m. in Crowsnest area, reduced rapidly to the east to less than 900 feet (274 m), suggest a nearer approach to the zone in which mountain building was active, probably in the southern part of the present western Rocky mountains.

Throughout the later stages of the Cretaceous, the eastern part of the basin shows little change in the deposits which were mainly marine clays. The western part, as exposed in the deposits of the faulted zone, shows repeated subsidences and elevations up to sea level. Active denudation of the western land areas is shown in conglomerates at the top of Benton shales exposed on Bow river and northward on the Brazeau and Athabaska rivers. Conglomerates also occur in the Belly River series at Crowsnest mountain and in the north in the Brazeau fields. This material was probably eroded from the hills appearing to the west, the prototypes of the western portion of the Rocky mountains.

The periods of elevation along the western margin of the interior region with the consequent changes in deposition, while not always prolonged, appear at one stage to have been of sufficient magnitude to allow the accumulation of a large body of brackish water deposits, the Belly River series. The surface so exposed was at times covered by vegetation, and thin coal seams were formed. This was subsequently covered by the marine deposits of the Pierre stage of Cretaceous time.

The close of the Cretaceous marine invasion is marked by the brackish water beds containing the coal seams of the Edmonton formation. During Tertiary time the deposits were distributed in fresh water and this part of the continent was raised to sea level—the distribution bringing in landlocked lakes or confined estuaries. The western Rocky Mountain ridges probably did not bar drainage from the gold bearing rocks of British Columbia, since the source of the gold in northen Alberta streams is credited to the lowest Tertiary or beds at the top of the Cretaceous.

The exact date at which elevation of the Rocky Mountains commenced is not certain, but it is probable that from early Cretaceous times the crust here was under strain and that at intervals during the warping of the crust before the close of that period the western part of the range had been marked out by hills which were being denuded of their top covering of shales, quartzites, and limestones to swell the accumulations in the Cretaceous sea to the east. The period of mountain building to which the elevation of the Rocky Mountains is assigned, the Laramide revolution, is probably a long one. The formation of the outer ranges with their frequent great overthrusts eastward, was subsequent to the elevation of the ranges of the watershed or to the deposition of the early Tertiary beds of the Paskapoo formation.

The denudation of post-Tertiary times has removed most of the broken material resulting from this late revolution, but the large well rounded pebbles in the Oligocene beds of the Cypress and Hand Hills, are probably the remains of that material. This period of mountain building is probably later than the Laramie and occurred between the Paskapoo or early Tertiary and the Oligocene.

Part of the denudation of the early Tertiary and Cretaceous beds of this basin may have been accomplished at this time, especially in the part near the mountains, but the greater part was due to a general elevation in Pliocene times, when much of the area was in process of reduction. The amount of material removed is well shown on the north side of Cypress Hills, where from the level of the Oligocene deposits the Saskatchewan river is now cutting through horizontal beds that are 2,000 feet (608 m.) below. The wasting away of material from the edge of the basin was also continued and before Glacial time the plateau of Cretaceous deposits assumed nearly its present form.

Many of the present valleys are broad depressions formed in pre-Glacial time, and sometimes show old stream gravels, derived from the Oligocene conglomerates, covered by the boulder till. Glacial deposits are spread over all the area, and, almost to the mountains, hold erratics derived from a northeastern source. The Cordilleran glacial material has been carried but a short distance eastward from the mountains.

The question of the extension of the continental ice sheet is still an open one and the glacial till west of the Coteau is believed by many to have been carried by floating ice. The closing stage of glaciation was no doubt one in which the ice front held back large lake-like basins, of which the best known is glacial Lake Agassiz which occupied the basin at the eastern edge of the Cretaceous plateau. This lake at first drained southward to the Mississippi valley, and at that stage formed many beaches along its western and southern margin. These beaches show a gradual rise to the north due to an upwarp of the crust, which caused the waters to continue their discharge southward until on the retreat of the ice to the north an outlet was found in that direction. Many of the former drainage channels were ice blocked, and the lake received a large inflow from the southern part of the plateau to the west of it. As a result of the valley cutting which ensued at this time, a great burden of fine-grained material was deposited in this basin to form the lacustrine deposits of the Manitoba plains.

SUMMARY DESCRIPTION OF FORMATIONS.

ORDOVICIAN.

In Manitoba the Ordovician includes the following formations:—

Stony Mountain formation, consisting of yellowish and reddish limestones overlying dark shales. Exposed at Stony Mountain.....	110 feet	(33·5 m.)
Upper mottled limestone..............	150 "	(45·7 m.)
Cat Head limestone..................	70 "	(21 m.)
Lower mottled limestone..............	70 "	(21 m.)

The divisions of the Trenton here indicated are made on physical grounds. The exposures are best seen on Lake Winnipeg. No deposits of this age occur in the outer ranges of the Rocky mountains.

SILURIAN.

The Silurian is composed of light-coloured, thin-bedded, yellow limestones. In the region to the east of Lake Manitoba important beds of gypsum are being mined from this formation.

DEVONIAN.

In Manitoba the Devonian rocks are divisible into three series as below:—

Upper Devonian or Manitoban, consisting of light gray, hard brittle limestone, with red argillites at the base, about..........................200 feet (64 m.)
Middle Devonian or Winnipegosan, consisting of light yellow, hard dolomite, with porous beds beneath, about..........................200 feet (64 m.)
Lower Devonian, mainly red shales. These beds probably represent only the upper part of the lower Devonian of eastern America, about ....100 feet (30 m.)

In western Saskatchewan these beds may be found near the Churchill river; having nearly the same characters.

In Alberta, the most eastern exposure is in the neighborhood of Athabaska river. In the Rocky mountains they form the Intermediate series, brownish, irregularly hardened dolomites, and greyish, crystalline dolomites, with some sandstones and quartzites.

CARBONIFEROUS.

These rocks are found in South Dakota, Montana, and Alberta. They are not exposed in Manitoba or along the northwest margin of the Cretaceous plateau, but are confined to the Rocky Mountain region. They have been subdivided on lithological grounds into upper and lower Banff limestones. These formations are each capped by shaly beds, from which have been obtained a few characteristic fossils. The formation is generally a bluish limestone, and forms the summits of Cascade and Rundle

mountains, near Banff. A thickness of over 6,000 feet (1,824 m.) for the formation has been observed in the Bow valley.

PERMIAN AND TRIASSIC.

At the top of the limestone series in the Rocky mountains, a series of quartzites overlaid by red shales may be in part Carboniferous, but as the series is conformable to the Jurassic, some deposition should be credited to Permian and Triassic. The red shales are occasionally capped by a thin band of yellowish dolomite, and often the series, on fresh exposures, shows yellow bands in the shales. Evidences of a Triassic age for the upper shales have been found in shells of *Monotis* type. These are recorded at Blairmore in the south and on branches of Brazeau river. Northward Triassic fossils have been found in Pine and Peace river valleys.

JURASSIC.

Fernie shale —In the locality where this formation received its name, Fernie, B.C., it consists of a series of black and brownish shales 1,060 feet (323 m.) in thickness overlying 500 feet (152 m.) of sandy argililtes. Eastward the series decreases in thickness. On the Cascade river the section is 1,600 feet (487 m.) and consists of black shales and grey sandstones with an occasional limestone bed toward the base. In the Moose Mountain area—an outlier of the Rocky mountains—the thickness is about 225 feet (68·5 m.). The formation has been traced northward to Athabaska river and preserves its general black, shaly appearance. Few fossils have been obtained in these measures, but they are characteristic:—*Cardioceras canadense*, *Peltoceras occidentale*, *Terebratula robusta*, *Ostrea skidegatensis*, *Exogyra* sp., *Lima perobliqua*, *Pteria corneuiliana*, *Trigonoarca tumida*, *Trigonia dawsoni*, *Astarte carlottensis*, *Protocardia hillana*, *Cyprina occidentalis*, *Pleurotonomya carlottensis*, *Schlœnbachia borealis*, *S. gracilis*.

CRETACEOUS.

Kootenay.—The lower member of this series of deposits is found resting upon the Jurassic in the Rocky mountains. In Manitoba it has not been recognized, and is

supposed to have formed but a very thin sheet east of the mountains. The base of the formation is a heavy bed of sandstone, which is succeeded by sandstones and shales containing many coal seams. A bed of conglomerate divides the formation in its northward extension, and few coal seams are found in the lower part. In the south the thicker seams are in the lower part. The greatest thickness occurs in the mountains and on Elk river in eastern British Columbia. Near Banff in Alberta the thickness is about 3,700 feet (1,127 m.). In the Bighorn basin this thickness continues. Eastward at Moose mountain it is only some 375 feet (114 m.). The fossils of the formation are plants, such as ferns, cycads, and conifers.

Dakota.—In the mountains above the coal bearing formation, occurs a series of conglomerates and sandstones that is not distinctly coal bearing, although thin coal streaks occur in it. Fresh water conditions prevailed in the mountain section and on the eastern margin during this period of deposition. In the lower part of Athabaska valley, the upper beds at least contain marine fossils.

The thickness of the formation in Manitoba cannot be much more than 200 feet (61 m.). In the foothills a thickness of 950 feet (290 m.) seems to represent the whole formation; but, westward in the Elk river escarpment, a shore deposit thousands of feet in thickness occurs at this horizon.

Benton.—Dark grey, almost black, shale of marine origin, forms a continuous sheet probably across the whole interior basin. In Manitoba the deposit is about 175 feet (53 m.) in thickness. In the foothills it is over 700 feet (213 m.), but this undoubtedly includes part of the overlying Niobrara. The entombed forms of animal life include *Inoceramus problematicus*, *Scaphites ventricosus* and *Prionscyclus woolgari*.

Niobrara.—In Manitoba, this formation consists of grey calcareous shales, which are an upward continuation of the Benton. Westward it is not so characterized in the marginal deposits there, since a period of unrest in the mountains occurred about that time accompanied by brief retreats of the shore line due to a slight rising of the crust. The formation is from 130 to 200 feet (40 to 61 m.) thick in the eastern part. The presence of foraminifera is a characteristic feature of the formation. The fossils include *Serpula semicoalita*, *Ostrea conjesta*, *Anomia obliqua*,

Inoceramus problematicus, *Belemnitella manitobensis*, *Loricula canadensis*, *Ptychodus parvulus*, *Lamna manitobensis*, *Enchodus shumardi*, and *Cladocyclus occidentalis*.

Pierre.—Marine deposits with little trace of calcareous matter succeed the Niobrara. In places almost 1,000 feet (304 m.) of shales are found in the formation. It is claimed that in the western part a great uplift occurred during the early part of this time interval, and brackish and fresh water deposits were formed and afterwards covered by marine beds before the close of the period. In Manitoba the marine sediments are divided into an upper or Odanah and a lower or Millwood. The time interval between the two may coincide with the period of uplift in the west. The western section is divided into *Bearpaw shales*, *Belly River series and Claggett shales.*

Claggett.—The "lower dark shales" of Dawson in southern Alberta have been given a thickness of 800 feet (243 m.). In Moose Mountain 250 feet (76 m.) of shale is supposed to represent this division. They are marine in origin and hold fossils of Pierre type.

Belly River.—This series of shales and sandstone beds are light-coloured and in appearance very much like the beds at the top of the Cretaceous. The fossils are brackish water types with probably fresh water forms in the upper part. Land conditions prevailed toward the close of this period of deposition and coal seams were formed. The measures extend eastward from the vicinity of the mountains into Saskatchewan. The thickness of the formation is about 800 or 900 feet (243 or 274 m.), but probably thins eastward. A similar series on the Peace river—the Dunvegan sandstones—probably belongs to this period.

Bearpaw.—The Pierre-Foxhill of Alberta and Saskatchewan is without doubt the equivalent of the Bearpaw of Montana. The formation in Alberta is about 700 feet (213 m.) in thickness. The fossils are marine and comprise among the common forms, *Baculites compressus*, *B. grandis*, *Scaphites nodosus*, *Placenticeras placenta*, *Inoceramus altus*, *I. nebrascensis*, *I. tenuilineatus*, and many others.

Edmonton.—In southern Saskatchewan the beds formerly called Laramie are divisible into a lower brackish water series and an upper fresh water one. The lower bears the same relation to the upper that the Edmonton does to the early Tertiary.

In southern Alberta the formations above the marine Cretaceous are divided in three subdivisions, the lowest of which at least forms part of the Edmonton division of northern Alberta. This is the brackish water portion of the formation, so called Laramie, and is generally placed at the top of the Cretaceous. The upper limit, the top of the coal horizon, may in time be considered Tertiary. The fossils consist of Dinosaurian remains, with land plants, and the following brackish water animal remains: *Ostrea glabra, Unio danae, Corbicula occidentalis, Panopæ simulatrix* and *P. curta*. The thickness of the formation varies but attains a maximum of 700 feet (213 m.) in central Alberta.

TERTIARY.

Paskapoo.—This series consists of fresh water deposits generally of yellowish sandstones and bluish grey and olive sandy shales. It embraces the upper part of the Laramie of southern Alberta and Saskatchewan, with a total thickness in western Alberta of 5,700 feet (1737m.). The remains of plants are numerous in it and denote a flora of a temperate climate. Fresh water fossils include: *Unio danæ, Sphaerium formosum, Limnæa tenuicostata, Physa copei, Acroloxus radiatulus, Thaumastus limnæiformis, Goniobasis tenuicarinata, Campeloma productus, Viviparus leai, Valvata filosa*, and *V. bicincta*.

Oligocene.—Isolated exposures of coarse grained material, deposited on the Paskapoo representative of the Tertiary in Saskatchewan, have been found to contain a considerable number of Mammalian bones. These beds are characterized by a great quantity of waterworn pebbles derived from the quartzites of the Rocky mountains.

ANNOTATED GUIDE.

Miles and Kilometres.

0 m.
0 km.

Winnipeg—Altitude 760 ft. (231 m.). The capital of Manitoba, population 130,000. The character of the country passed through east of this city shows a gradual change from the hilly surface of the Pre-Cambrian shield to an apparently level plain. This is the lake bottom of a former lake of Glacial time called

Miles and Kilometres.

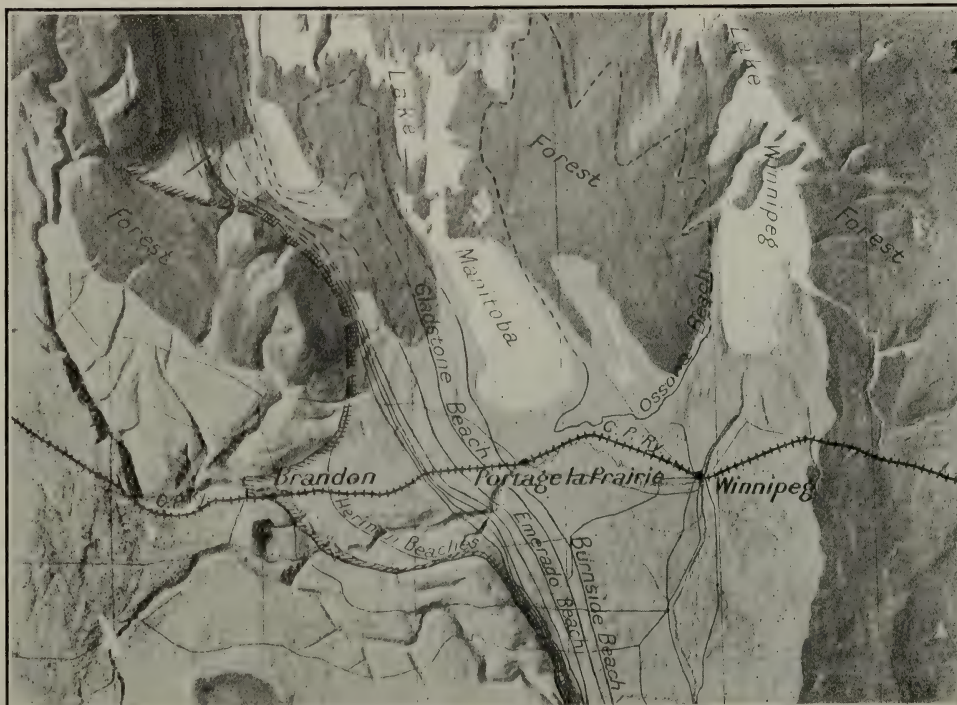
Lake Agassiz. The sediments at the south end of this basin were brought in very rapidly by a strong system of drainage across the Cretaceous plateau to the west, and the erosion of the soft rocks of that region provided abundant material for filling inequalities in the rock surface forming the bed of the lake. At its highest stage Lake Agassiz extended southward to Lake Traverse in Minnesota and drained to the Mississippi valley. At Winnipeg, the depth of water was about 560 feet (170 m). Beaches along the western margin were formed at several stages of the lake recession and these show an upwarping of the crust. A vertical projection of the beaches accompanying this description shows graphically the amount of this movement. The subsidence of the lake, with the retreat of the ice barrier to the north-east, did not at once alter the direction of drainage, and the southward flow was maintained for several stages owing to the upwarp to the north. An outlet northward was found while the water was 240 feet (73 m) deep over the position now occupied by the city of Winnipeg.

In going westward from Winnipeg the rise is very slight across the lower part of the old lake basin, and, since the railway ascends to the rim of the basin on the delta of the principal stream tributary to the lake, beaches are not strongly in evidence. These are however strongly marked both to the north and south and are indicated in the accompanying illustration.

55 m. 88 km. **Portage la Prairie**—Altitude 851 ft. (259 m).

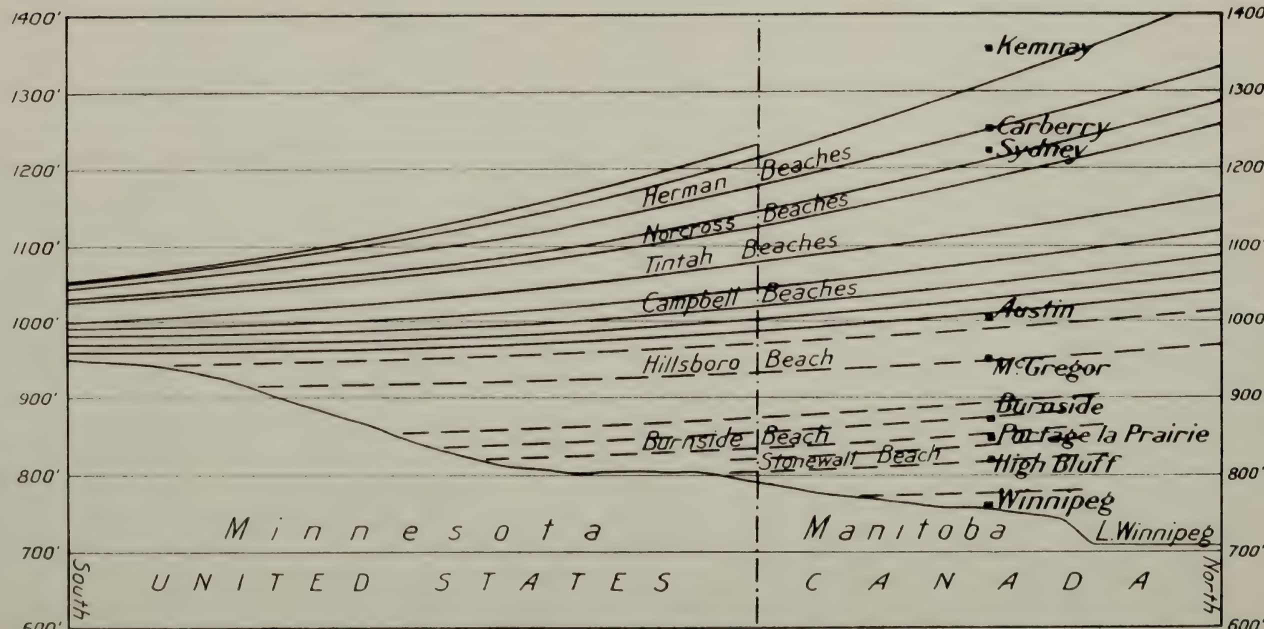
62 m. 100 km. **Burnside**—Altitude 869 ft. (265 m.). Shortly after passing Portage la Prairie the railway crosses a succession of beaches of the ancient glacial Lake Agassiz: the Burnside beach four miles west of Portage la Prairie, and the Gladstone beach two miles (3.2 km.) beyond Burnside near Rat creek.

70 m. 112 km. **Bagot**—Altitude 936 ft. (285 m.).



Plan of beaches of Lake Agassiz in Manitoba.

Miles and Kilometres.	
77 m. 124 km.	**MacGregor**—Altitude 956 ft. (291 m.). At the 69th mile post, or about two miles (3.2 km.) west of Bagot, is the Emerado beach, and one mile (1.6 km) west of MacGregor the lowest of the Blanchard beaches is crossed.
84 m. 135 km.	**Austin**—Altitude 1,015 ft. (309 m.). When the level of Lake Agassiz stood about the level of Austin its drainage changed from flowing southward into the Mississippi and found an outlet northward to Hudson bay.
105 m. 169 km.	**Carberry**—Altitude 1257 ft. (383 m). Beaches marking a higher stage in the level of the lake are crossed by the railway before reaching this point, but they are indistinct and not well marked. They may however be found at the following points: at 86.9 miles (27 km.) from Winnipeg is the lower Campbell beach; at 87.5 miles (26.6 km) the upper Campbell beach. Immediately west of Carberry the Herman beaches are to be seen.
132 m. 212 km.	**Brandon**—Altitude—1199 ft. (365 m.). The evidences of Lake Agassiz are very slight at Brandon and as it is situated on the estuary of the ancient Assinboine river at the highest stage of the lake, delta deposits only can be found.
157 m. 253 km.	**Griswold**—Altitude 1421 ft. (433 m.). Slight evidences of morainic material occur between Brandon and Griswold which mark the position of the ice front when glacial Lake Souris was in existence. This lake had not the dimensions of Lake Agassiz. It drained southward by the Pembina river.
264 m. 425 km.	**Broadview**—Altutude 1961 ft. (598 m.).
356 m. 573 km.	**Regina**—Altitude 1884 ft. (564 m.). Regina is the seat of government for the province of Saskatchewan and is situated on a level plain near the western edge of the second prairie steppe.
398 m. 640 km.	**Moosejaw**—Altitude 1766 ft. (53 8m.). To the south and west of Moosejaw the low rounded



Projection of beaches of Lake Agassiz in vertical section.

Miles and Kilometres.

hills of the Coteau can be seen rising somewhat abruptly from the level prairie. These hills are the erosion remnants of Tertiary deposits. South of Moosejaw are exposures of white silts and clays, and important deposits of fire clay. Coal seams also occur in these measures.

424 m.
682 km. **Mortlach**—Altitude 1975 ft. (602 m.). The cuttings along the railway here show deposits of boulder clay in irregular shaped hills. Small pebbles occur in the clay, and large boulders appear at the surface.

433 m.
697 km **Parkbeg**—Altitude 2062 ft. (628 m.). The ascent to the third prairie steppe is made through a gap in the hills of the Coteau, and glacial drift is much in evidence which, however, here shows an admixture of material derived also from the underlying sandy beds. Six miles (9.6 km.) west of Parkbeg the boulder clay encloses a body of sandstone evidently removed from the rocks beneath. Morainic material is spread all along the eastern face of these hills, and it is still an open question whether the drift farther west was deposited by floating ice or by a farther advance of the glacial ice front.

508 m.
817 km. **Swift Current**—Altitude 2,420 ft. (736 m.). Beyond Parkbeg the railway follows the plain which slopes northward from Cypress hills and which is underlain by rocks belonging to the Pierre division of the Cretaceous. At Forres station

612 m.
985 km. **Forres**—Altitude 2,465 ft. (751 m.).

the Belly River series comes to the surface, and the rocks of which it is composed outcrop in the hillsides all the way to Medicine Hat. Sections of these rocks are best seen at Redcliff on the north side of the valley of South Saskatchewan river. Near the town and to the east of it the river banks show a great thickness of till.

656 m.
1,056 km. **Medicine Hat**—Altitude 2,168 ft. (661 m.). Natural gas has been found in the lower part of the Belly River series and also in the sandy beds of the continuation of the Dakota. At

Miles and Kilometres.

Medicine Hat the supply is all drawn from depths between 400 (122 m.) and 1,000 feet (304 m.). Gas for various manufacturing processes and power, as well as for heat and light, is available. The city has several wells 1,000 feet (304 m.) in depth with a pressure of 560 pounds capped. Three of these are capable of furnishing 5,000,000 cubic feet of gas per twenty-four hours. Gas is also supplied by several privately owned wells. One owned by the Canadian Pacific railway supplies their shops with 1,250,000 cubic feet per twenty-four hours.

662 m. 1,065 km. **Redcliff**—Altitude 2,428 ft. (740 m.). Brick and other clay products are manufactured at this point at two separate plants, and the burning is done by natural gas. The clay used is from the Belly River formation. To the south the Cypress hills are in view.

Between this point and Calgary the Canadian Pacific Railway company has undertaken to irrigate a large area of farm land, drawing water through large irrigation ditches from the Bow river at Calgary and Bassano.

722 m. 1,162 km. **Brooks**—Altitude 2,476 ft. (755 m.). The top of the Belly River formation is reached at this station. To the west the Rocky Buttes rise in a line of hills marking the eastern edge of the sandy deposits of the top of the Cretaceous. The dark shales of the Pierre (the Bearpaw of Montana) underlie the country to Bassano.

745 m. 1,213 km. **Bassano**—Altitude 2,584 ft. (788 m.). The eastern edge of the Edmonton series is crossed near Bassano. To the south is the valley of Bow river.

762 m. 1,226 km. **Crowfoot**—Altitude 2,698 ft. (822 m.). Coal seams occur in the valley at this place and are mined to some extent by the Blackfoot Indians. These Indians hold in reserve a large block of land to the south of the railway, and the government maintains an agent at Gleichen to teach them farming and to oversee the providing of food and clothes for the aged.

Miles and
Kilometres.

816 m.
1,313 km. **Langdon**—Altitude 3,289 ft. (1002 m.). Important towns have grown up along the railway as the result of the irrigation of this section by the Canadian Pacific Railway company.

836 m.
1,345 km. **Calgary**—Altitude 3,425 ft. (1044 m.). This fast growing city is becoming a railway centre and manufacturing town. Tertiary rocks of the Paskapoo series, outcrop in this vicinity and are quarried for building stone.

859 m.
1,382 km. **Cochrane**—Altitude 3,748 ft. (1142 m.). Here the railway line follows closely the valley of Bow river, which cuts through the sandstones of the Paskapoo series. At Cochrane the beds dip east and form part of the great syncline occupied by Tertiary rocks. The underlying coal-bearing beds are brought up to the surface and at Radnor a seam in the Belly River formation is being mined. Many flexures and folds occur between this point and the mountains.

890 m.
1,432 km. **Kananaskis**—Altitude 4,218 ft. (1285 m.).

In the hills immediately north of this station, limestones of the top of the Cambrian have been overthrust on Cretaceous of the Belly River formation.

893 m.
1,437 km. **Exshaw**—Altitude 4,247 ft. (1294 m.). Cement manufacturing is the principal industry at this point and the plant is one of the largest in Canada. Limestone is quarried from the mountain side, but shale is now being brought from near Laggan.

903 m.
1,453 km. **Canmore**—Altitude 4,283 ft. (1305 m.). This town is situated on the western edge of one of the wide fault blocks from which a great section of Lower Cretaceous has been eroded in the formation of the valley. Southward along the mountain front remnants of these

Miles and Kilometres.

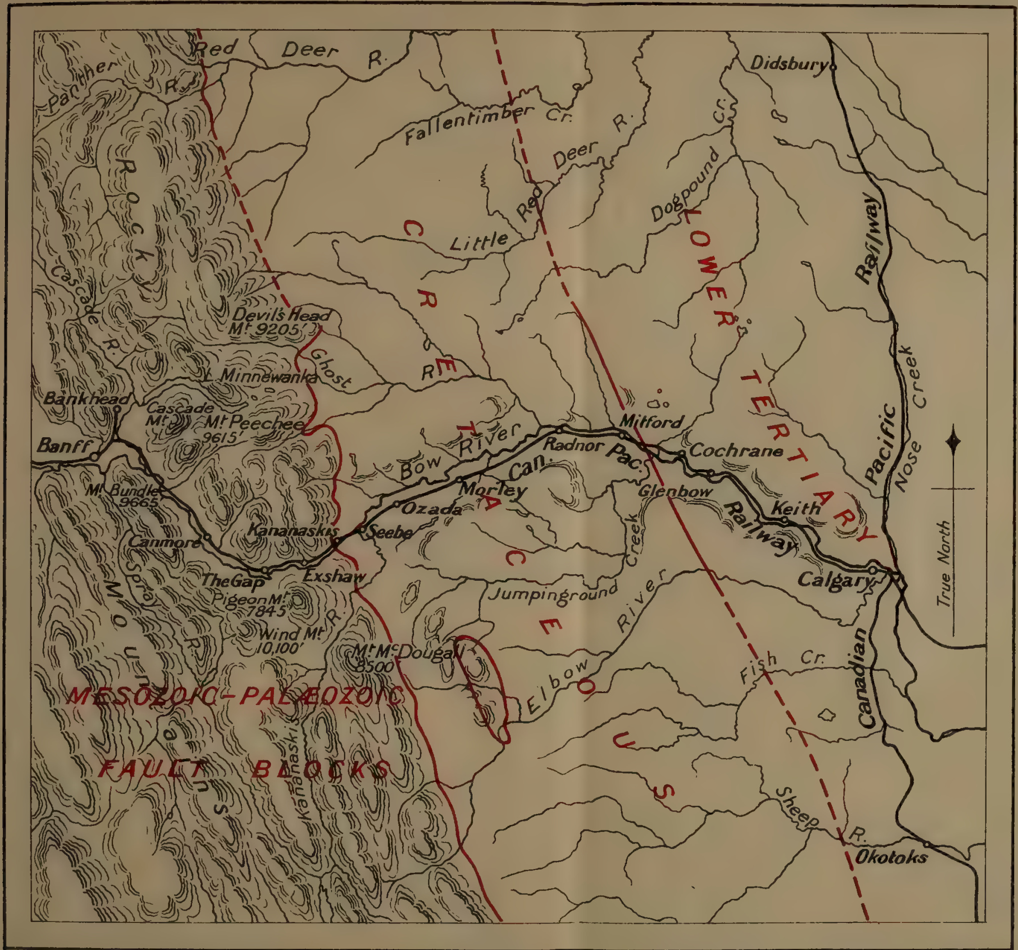
beds occur. A narrow westerly dipping fringe of the coal bearing beds is being mined below the surface at this point. Behind the town, cliffs of Devonian and Carboniferous limestones show the eastern edge of the succeeding fault block.

916 m.
1,474 m.

Bankhead—Altitude 4,569 ft. (1393 m.). In front of Cascade mountain the continuation of the coal measures forms a buttress in which the beds dip towards the fault line. Mining is carried on by an entry driven from the valley level. The cross-cut tunnel from this entry cuts the measures and intersects several seams.

The measures in which these seams occur constitute a block dipping to the southwest toward Cascade mountain. At the south end of the block they pass under the limestone. At the north end, up Cascade river, the measures are bent up in a syncline, but further on they have been entirely eroded away.

A section measured near the mine at Bankhead gives a total thickness of 2,800 feet (853) of possibly coal bearing rocks, with 550 feet (167 m.) of thin bedded brown sandstones and shales above them. The measures consist of sandstones and shales of a generally brown colour, and, in this vicinity, three of the heavy sandstone beds form strong ribs. The upper and lower sandstone ribs seem to define the upper and lower limits of the coal formation, which has a thickness of 1,100 feet (335 m.). Below is a series of sandstones and shales very similar to those higher up. The passage to the Fernie shales is conformable, and is marked by an absence of sandstone. The Fernie shale consists of 1,360 feet (445 m.) of dark grey to black shale overlying 240 feet (73 m.) of dark greyish thin-bedded sandstone, the whole of marine origin and assigned to the Jurassic period. These beds are exposed on the river sides above the mine.



Geological Survey, Canada

Route map between Calgary and Banff

The following tabular statement shows the thickness of the coal seams and associated beds and their succession:—

	Feet.	Inches.	Metres.
Seam No. 0.			
Thickness between roof and floor......	5	9	1·7
Coal..................................	3	0	·9
Thickness between No. 0 and No. 1.....	33	....	10·0
Seam No. 1.			
Thickness between roof and floor......	12	0	3·6
Coal in thin bands....................	7	11	2·4
Thickness between No. 1 and No. 2....	30	....	9·1
Seam No. 2.			
Thickness between roof and floor......	18	0	5·5
Coal (one clean part, 8 ft.)...........	10	11	3·3
Thickness between No. 2 and No. 3....	92	....	28·0
Seam No. 3.			
Thickness between roof and floor......	29	6	8·9
Coal (two benches 14 ft. and 5 ft.).....	19	....	5·8
Thickness between No. 3 and No. 4....	150	....	45·7
Seam No. 4.			
Thickness between roof and floor......	17	3	5·25
Coal (in three benches 6 ft., 3 ft., 4·5 ft.)	13	6	4·1
Thickness between No. 4 and No. 5....	60	....	18·3
Seam No. 5.			
Thickness between roof and floor......	12	3	3·7
Coal (in the top part)................	6	....	1·8

GUIDE BOOK No. 8

Transcontinental Excursion C1

Toronto to Victoria and return via Canadian Pacific and Canadian Northern Railways

PART II

ISSUED BY THE GEOLOGICAL SURVEY

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1913

GUIDE BOOK No. 8.

Part II.

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INTRODUCTION TO THE GEOLOGY OF THE CORDILLERA.

BY

REGINALD A. DALY.

GENERAL TOPOGRAPHY.

The North American Cordillera, extending from Bering Sea to the intersection with the Antillean mountain system, has a length of 7,000 kilometres (4,350 miles), an average breadth of about 900 kilometres (560 miles), and an area more than two-thirds that of all Canada and nearly two-thirds that of Europe. This gigantic feature of the earth is a tectonic unit, originating in stresses specially exerted from the Pacific basin. The Cordillera as a whole has, therefore, been fitly called the Pacific Mountain system of North America.

The members of Excursion C1. will cross the system where it is comparatively narrow; nevertheless, a straight-line measurement of its width is here about 700 kilometres (435 miles). Along the somewhat tortuous route of the Canadian Pacific railway, the distance from the eastern foot of the mountains to the city of Victoria is 1,050 kilometres (650 miles). For purposes of geological description and of orientation in the field, it is necessary to review the general subdivision of the Pacific Mountain system at the railway section.

Among the conceivable criteria for subdivision, the purely topographic principle used by G. M. Dawson seems to be the only practical one. In the first place we may distinguish a belt characterized by plateau forms and thereby contrasted with the rest of the Cordillera in the Dominion of Canada. This may be called the Belt of Interior Plateaus. It lies on the eastern side of the Coast range, which is of alpine habit. Elsewhere the subdivision of the mountain chain follows the lines of the master valleys.

The greatest of the intermont depressions is that extending from Flathead lake in Montana to the Yukon boundary, a distance of 1,600 kilometres (990 miles). It is a relatively narrow but actually imposing trough, successively drained by head-waters of most of the great rivers of the

Sketch map showing major subdivisions in the southern part of the Canadian Cordillera.

Canadian part of the chain: namely, the Columbia, Fraser, Peace and Liard—the last two being principal branches of the Mackenzie river. The larger streams flowing in the depression are: the Kootenay; the Columbia; the Canoe river; the Fraser; the Parsnip and Finlay rivers (Peace river system); and the Kachika river of the Liard system. Many of them leave the trough by transverse gorges cut in the adjacent mountains. The rivers enumerated, as well as smaller ones not specially named, are arranged in regular sequence, draining the trough in opposite (N.W. and S.E.) directions. Although continuous throughout its great length, the trough is not a valley in the ordinary sense. It is like a trench dug by soldiers in a hilly country; such a defensive work is not cut to a uniform bottom grade but is man-deep whatever the slope. This master form in the Cordillera may be appropriately described as a topographic trench. All the mountains in Canada and in Montana lying to the northeastward of the trench have long been segregated as the Rocky Mountain system, and the bounding trough has been named the *Rocky Mountain trench.*

A second trench, about 350 kilometres (220 miles) in length, opens in the southeastern wall of the first near Beavermouth and runs southward. It is successively drained by Beaver river, Duncan river, and Kootenay river; for 120 kilometres (74 miles) it is occupied by the fiord-like Kootenay lake. This trough rigorously separates the Purcell Mountain range on the east from the Selkirk system on the west and bears the name, *Purcell trench.* The Purcell range is thus bounded, east and west, by the two trenches; on the south it terminates at the loop of the Kootenay river in Montana and Idaho.

Near latitude 52° the Columbia river leaves the Rocky Mountain trench and flows south, in a wide valley 500 kilometres (310 miles) long, to the Columbia lava-field of Washington State. This part of the Columbia valley may for convenience be called the *Selkirk valley.* Midway in its course it bears the Arrow lakes, totalling 150 kilometres (92 miles) in length. East of the Selkirk valley and west of the two master trenches is the Selkirk Mountain system which, like the Rocky Mountain and Purcell systems, extends into the United States.

The rugged mountains to the west of the Selkirk valley have been grouped under the name, Columbia

Looking southeast from Six Mile creek along the Purcell Trench (Beaver River valley).

mountain system. On the north this system is bounded by the obliquely truncating Rocky Mountain trench; and on the south by the lava plateau of Washington. Toward the west the Columbia mountains become less alpine and assume a rough-plateau character, so that it is not possible to make a clean-cut line of division from the adjacent Belt of Interior Plateaus. This zone of topographic transition is crossed by the railway in the region of the

Looking south from Terminal Peak along the edge of the great escarpment bounding the Purcell Trench on the west.

Shuswap lakes. The Fraser valley at and in the vicinity of Lytton forms a convenient and more definite limit to the Belt of Interior Plateaus, on the west.

The Coast range extends from the Fraser valley to the structural depression occupied by the Strait of Georgia and Queen Charlotte sound, to the westward of which is the Vancouver range of Vancouver island. On the south the Coast range terminates at the transverse portion of the Fraser valley, which also delimits the Cascade range entering British Columbia from the United States.

In the larger view, the Canadian Cordillera may be broadly divided into four provinces: (a) the Rocky Mountain system; (b) the Middle or Interior ranges, including the Purcell, Selkirk, Columbia and Cariboo mountains; (c) the Belt of Interior Plateaus; and (d) the Coastal system, including the Coast range, the Cascade range, and the Vancouver-Queen Charlotte range. The first, third, and fourth of these provinces extend, with but minor interruptions, through Yukon Territory and Alaska to Bering Sea. The Middle ranges as a whole are specially broad in southern British Columbia, but narrow rapidly to the northward and, in the United States, have been broadly depressed and covered by the lava floods of Idaho and Washington states.

GLACIATION OF THE CORDILLERA.

The field habit of the visible glaciated rock-surfaces and the condition of the drift deposits, in these Canadian mountains, strongly suggest that the great glaciers of the Cordillera were essentially contemporaneous with the eastern ice-cap at its Wisconsin stage. No facts yet determined on the mainland of British Columbia or in Alberta have shown clearly that general Pleistocene glaciation was multiple. It is true that, at many points within the Cordillera and along its piedmonts, younger till rests on water-laid silts, sands, or gravels of Pleistocene age; but this relation is that normal to the inevitable oscillation of ice-fronts during a single glacial period and it is still unsafe to postulate a general interglacial epoch for the Cordillera. However, further investigation of its interior portion may demonstrate one or more interglacial periods, even in spite of the fact that, in a topography so strongly accidented, a more recent glaciation must tend to obliterate the traces of an earlier one.

When at their maximum, the Pleistocene glaciers of the mainland formed an interior ice-cap flanked by double rows of valley glaciers. The ice-cap was fed by the local sheets respectively draining the western versant of the Rocky Mountain system and the eastern versant of the Coast range. The eastern slope of the Rockies was drained by many large valley glaciers. These often became confluent as piedmont sheets on the plains of

Alberta. Similarly, the western slope of the Coast range bore heavy glaciers which formed thick and broad piedmont sheets filling Puget sound, the Strait of Georgia, and Queen Charlotte sound.

Dawson located the main accumulator of the ice-cap in the interior of the Cordillera between latitudes 54° and 59°, and proved the northward flow from that region as far as 63° N., as well as a southward flow over the 49th parallel into Washington State. Locally, the ice-cap sent thick distributary sheets through low cols and valleys crossing the Coast range; of these the Fraser valley is a signal instance. At many points the surface of the en-era ice-cap is known to have risen somewhat above the 7,000-foot (2,134-metre) contour. Its thickness at the Okanagan valley was at least 6,000 feet (1,830 m.); at Revelstoke about 5,500 feet (1,677 m.).

Nothwithstanding its massive proportions, the ice-cap performed comparatively little erosion. Area for area, this necessarily sluggish body was incomparably less powerful in cutting into bed-rock than were the neighbouring valley glaciers. These were usually much swifter because occupying lines of more concentrated flow. The influence of such concentration, caused by mountainous topography, is extremely clear in the Canadian Cordillera, and the principle leaves no ground for controversy as to the efficiency of glacial erosion.

A smaller, independent ice-cap covered Vancouver island, and another, or else a large number of local glaciers occupied the Queen Charlotte islands.

GENERAL STRATIGRAPHY.

The section along the Canadian Pacific railway offers an almost complete representation of the main rock systems known in the Canadian Cordillera. The variety of the formations is explained partly by the transverse character of the section through a belted mountain chain; partly by the specially extensive uplift and exposure of the oldest rocks in this geological province. Only the Pliocene and the Miocene fail to appear in the list of standard rock systems, which here ranges from the Pre-Cambrian (pre-Beltian) to the Pleistocene. In the succeeding table the more important formations, with thicknesses, are named in

order. The measurements and estimates are founded on considerable, more recent field-work supplementing the reconnaissance studies of G. M. Dawson. [**5,** p. 62].

The total of the maximum thicknesses is colossal (135,000 feet (41,150 m.), including 25,000 feet (7,620 m.) of volcanics), but there can be no doubt that it is correct as to the order of magnitude. Notwithstanding all possible errors of mensuration, it seems clear that the Beltian-Paleozoic geosynclinal prism of the Selkirk-Rocky Mountain region had a thickness greater than 50,000 feet (15,240 m.). Dr. J. A. Allan has found more than 40,000 feet (12,192 m.) of conformable sediments in the Rocky mountains. The still older strata of the Selkirks are nearly or quite as thick.

TABLE OF CORDILLERAN FORMATIONS.

System.	Formation.	Thickness.	
		Feet.	Metres.
Recent and Pleistocene.....	Fluviatile, lacustrine, glacial............... *Unconformity.*	....	....
Oligocene (?)........	Kamloops volcanic group	3,000+	914+
	Tranquille beds (largely tuffs)................ *Unconformity.*	1,000	305
Eocene.............	Coldwater group (conglomerate, sandstone, etc.) of Interior......	5,000	1,524
	Puget group of Coast...	....	....
	Rhyolite porphyry at Ashcroft............ *Unconformity*	....	....

TABLE OF CORDILLERAN FORMATIONS—*Continued.*

System.	Formation.	Thickness. Feet.	Thickness. Metres.
Lower Cretaceous (Comanchean)....	Jackass Mountain group and Queen Charlotte Islands group (sandstones, shales, conglomerates) of the west..............	....	....
	Upper Ribboned sandstone................	550	168
	Kootenay Coal Measures Rocky Mts...........	2,800	853
	Lower Ribboned Sandstone................	1,000	305
	Spence's Bridge Volcanic group..............	....	....
Jurassic............	Fernie shale of Rocky Mts.................	1,500	457
	Upper part of Nicola group (Interior)......	....	....
Triassic............	Lower part of Nicola group (basic volcanics with limestone........	10,000∓	3,048∓
	Boston Bar group of Coast range (Triassic?)	....	....
Unconfor	*mity with Pennyslvanian.*		
Permian............	Upper Banff shale......	1,400	427
Pennsylvanian......	Rocky Mountain quartzite (thickness, 244m.) Upper Banff limestone (thickness, 701 m.)....	Rocky M	ts.
	Cache Creek group of the Western Belt (quartzite, limestone, basic volcanics)............	9,500	2,896

TABLE OF CORDILLERAN FORMATIONS—*Continued.*

System.	Formation.	Thickness.	
		Feet.	Metres.
Mississippian.......	Lower Banff shale......	1,200	366
	Lower Banff limestone (partly Devonian)....	1,500	457
Devonian...........	Intermediate limestone..	1,800	548
	Sawback limestone (Devonian?); (thickness, 1,128 m.)...........	....	....
Silurian............	Halysites beds..........	1,850	563
Ordovician..........	Graptolite shale........	1,700	518
	Goodsir shale...........	6,040	1,841
Upper Cambrian....	Ottertail limestone......	1,725	526
	Chancellor shales.......	4,500	1,372
	Sherbrooke limestones...	1,375	419
	Paget limestones........	360	110
	Bosworth limestones....	1,855	565
Middle Cambrian...	Eldon limestones........	2,728	831
	Stephen limestone-shale	640	196
	Cathedral limestones....	1,595	486
Lower Cambrian....	Mt. Whyte sandstone shale.... } Rocky Mts.	....	....
	St. Piran quartzite.......... } Rocky Mts.	....	....
	Lake Louise shale } Rocky Mts.	....	....
	Fairview sandstone......... } Rocky Mts.	....	....

TABLE OF CORDILLERAN FORMATIONS—*Concluded.*

System.	Formation.	Thickness.	
		Feet.	Metres.
	Sir Donald quartzite........ } Selkirk Mts.	5,000	1,524
	Ross quartzite, upper part...... } Selkirk Mts.	2,750	838
	Conformity in Selkirk Mts; local unconformity in Rocky Mts.		
Beltian.............	Ross quartzite (lower part)................	2,500	762
	Nakimu limestone......	350	107
	Cougar quartzites.......	10,800	3,292
	Laurie metargillites.....	15,000	4,572
	Illecillewaet quartzite...	1,500	457
	Moose metargillite......	2,150	655
	Limestone.............	170	52
	Basal quartzite.........	280	85
	Unconformity.		
Pre-Beltian .... (Shuswap series)	Adams Lake greenstones	10,000	3,048
	Tshinakin limestone-metargillite..........	3,900	1,188
	Bastion schists (phyllites, etc.)................	6,500	1,981
	Sicamous limestone.....	3,200	975
	Salmon Arm mica schists.	1,800	548
	Chase quartzite.........	3,000	914
	Tonkawatla paragneiss (?)............	1,500	457
	Base concealed.		
	Total thickness (minimum)	135,018	41,150

The more important volcanic formations are listed in the table. A few subordinate bodies of lavas and pyroclastics, together with very numerous intrusive masses, will be noted in the sequel. Igneous activity is registered in the pre-Beltian, Beltian, Palæozoic, Mesozoic, and Cenozoic eras.

Shuswap Terrane.

Detailed work has been only begun on the widely exposed pre-Beltian rocks, which form the crystalline base ment of British Columbia and share the complexity of the "Archean" in all parts of the world. They consist of a very thick, conformable, bedded group, called the Shuswap series, and a younger group of granitic intrusives. The whole complex may be conveniently named the *Shuswap terrane.*

Shuswap Series—Owing to structural difficulties, to the ruggedness of the mountains, and especially to a dense forest cover, it has not yet proved possible to construct a definitive columnar section for the Shuswap series. It is best exposed on the shore-lines of the Shuswap lakes and of Adams lake, during the low-water season of the year. However, one can seldom follow a contact or other structural plane far from the lake shore. Faults, thrust-planes, and folds are unusally difficult to map in this thoroughly metamorphosed mass of sediments and volcanics. Neither the top nor the bottom of the series has been found. The oldest sediments are interleaved with, and underlain by, intrusive granites, chiefly developed as sills. The youngest member on Adams lake where it is best exposed, is truncated by the present erosion surface.

Obscure as the structures generally are, it is quite clear that the Shuswap series is exceedingly thick. A provisional columnar section may be stated, as follows:

Tentative Columnar Section of the Shuswap Series.

	Thickness. Feet.	Metres.
Top, erosion surface.		
Adams Lake formation; greenstone schists.	10,000	3,048
Tshinakin formation:		
Limestone (1,500 ft., 457 m.)		
Phyllitic metargillite (800 ft., 244 m.)		
Limestone (1,600 ft., 488 m.)		
Total..........................	3,900	1,188
Bastion schists, phyllite with green schists at top..............................	6,500	1,981
Sicamous limestone.....................	3,200	975
Salmon Arm schists, micaceous............	1,800	547
Chase quartzite.........................	3,000	914
Tonkawatla paragneiss	1,500+	457+
Base concealed		
	29,900	9,111

The *Tonkawatla formation* is exposed in a series of railway cuts 3 miles (5 km.) west of Revelstoke. It consists of a dark-coloured, massive, homogeneous, comparatively fine-grained gneiss bearing thin interbeds of white crystalline limestone. The latter are seldom over 2 inches (5 cm.) in thickness but are locally numerous. Their presence suggests that the whole group of rocks here exposed is of sedimentary origin. The gneiss is rich in biotite and plagioclase and is probably best interpreted as originally a calcareous argillite. The paragneiss passes upward into yet more massive, harder biotitic quartzite, which also carries thin intercalations of limestone.

Quartzite of identical habit and tentatively ascribed to the same horizon, is exposed on the slope due south of Shuswap station near the village of Chase. Here the thickness is to be measured in hundreds of metres and a special name, *Chase quartzite*, has been given to the member. Besides the thin beds of limestone, the quartzite often shows abundant disseminated grains of carbonate, largely calcite.

At Shuswap station the massive Chase quartzite is directly overlain by coarse, glittering muscovite-biotite schist, often garnetiferous and seamed with beds of micaceous quartzite. As usual in the Shuswap series, the planes

of bedding and schistosity are coincident. A thickness of some 1,500 feet (457 m.) is locally represented in these schists. They appear to be of the same horizon as a group of schists exposed in still greater strength on Salmon Arm of Shuswap lake; the name *Salmon Arm schist* may be given to the member. The coarse crystallization of the plainly sedimentary formation is due to the contact metamorphism of countless granitic sills and laccoliths. On the cliffy slopes at the eastern end of Bastion mountain the coarse schists pass up gradually into phyllite, a less metamorphosed phase.

On the slope just mentioned the Salmon Arm schists are conformably overlain by the thick *Sicamous limestone*, named for its occurrence at Sicamous station. This is a thin-platy, light bluish-gray to dark gray or almost black limestone, generally interrupted by closely spaced sericitic films. The range in colour tints is due to variation in the amount of carbonaceous matter disseminated through the limestone. The rock effervesces with cold dilute acid, but it is somewhat magnesian.

The western slope of Bastion mountain is in part underlain by the *Bastion schists* conformably overlying the Sicamous limestone These are best exposed on the shore of the lake, north of Canoe point opposite Sicamous. They are chiefly sedimentary phyllites but at the top are green schists, apparently of volcanic orgiin.

On Adams lake, schists like the last-mentioned rocks, are conformably overlain by the composite *Tshinakin formation*, which, in turn, is there conformably overlain by a gigantic series of greenstones and green schists, the *Adams Lake formation*, enclosing rare interbeds of limestone and phyllite. To this youngest recognized member of the Shuswap series Dawson gave the name "Adams Lake series", and he regarded it as of Cambrian date and of volcanic origin. More recent work has referred it to the Pre-Beltian series. Dawson estimated the thickness of these volcanics as 25,000 feet (7,620 m.); the apparent thickness is certainly greater than 10,000 feet (3,048 m.).

No complete field section has yet been found in the great Shuswap terrane and several of the horizons have been brought into the described relations through lithological similarities in different sections. That principle is of specially hazardous application in a region of complete metamorphism like that now under consideration. The

Bastion mountain from the west, showing the Sicamous limestone (in the high bluff) overlain by the Bastion schists (background, on the left). The large outcrop near the middle of the view is intrusive syenite.

table of formations will therefore surely need emendation. Nevertheless, it will serve to give a picture of the leading stratigraphic inferences so far made and to indicate in a qualitative way the magnitude and variety of the formations composing the Shuswap series.

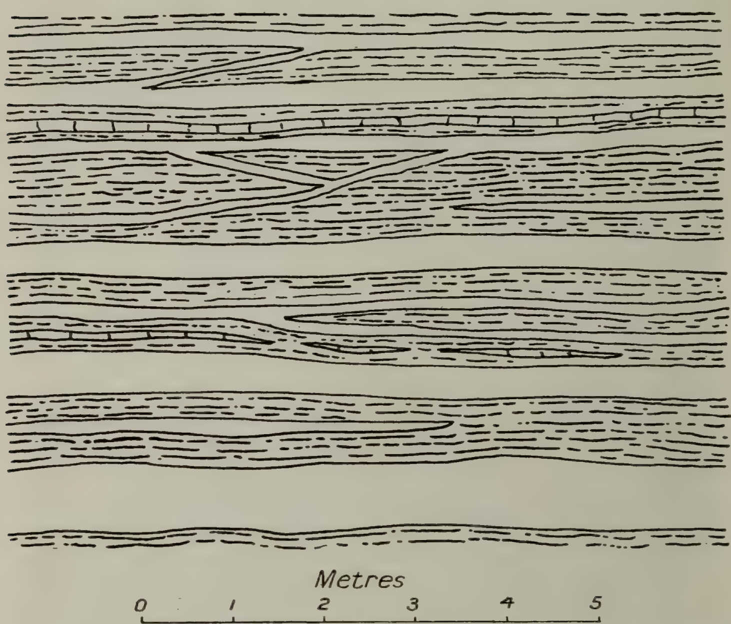


Diagram showing metasedimentary schists, thin limestone interbeds, and intrusive sills (left blank) of the Shuswap terrane, in typical relations; locality near Carlin siding.

Orthogneisses and Intrusive Granites.—Without exception each member of the Shuswap series has been intruded by granitic magma of pre-Beltian age. Some of the largest of these intrusive bodies are true cross-cutting batholiths which have developed strong metamorphic aureoles. However, most of the intrusions, literally innumerable, are not subjacent or bottomless but are to be classed with the 'injected' bodies. Sills are specially conspicuous. Some of the injections are thick and apparently of laccolithic form and mechanism; others have roofs and floors, but cross-cut the bedded formations and these may be described as chonoliths. Dykes are

Aplitic and pegmatitic sills cutting rusty metasedimentary schists and limestone interbeds; Shuswap terrane, western shore of Mara Arm of Shuswap lake.

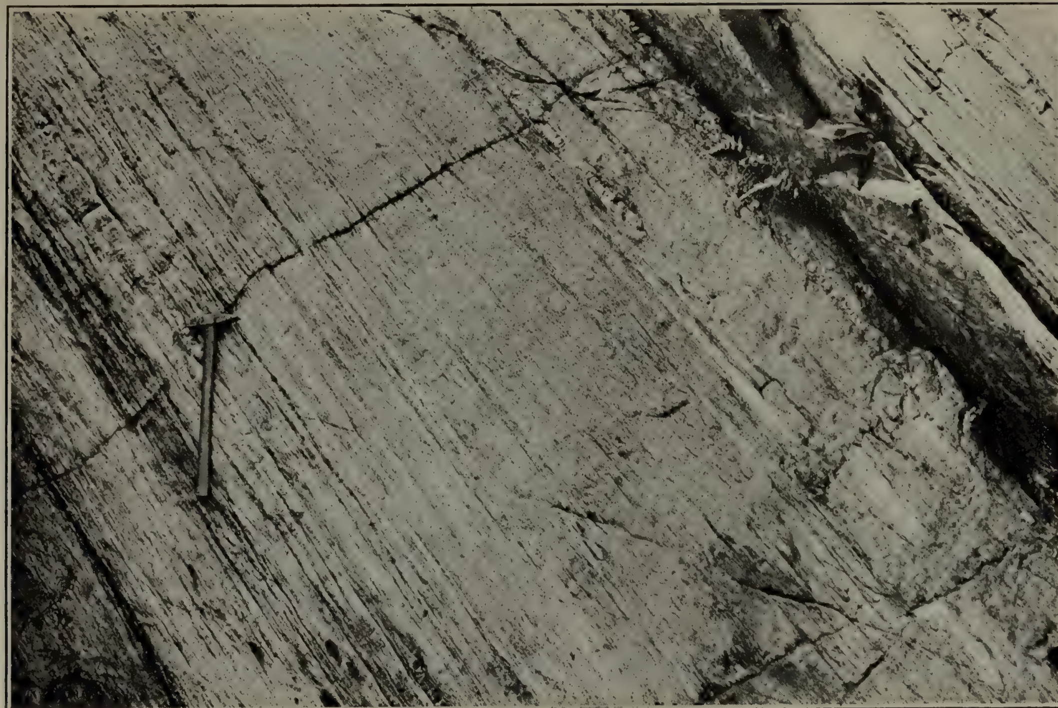
very numerous, in part representing the feeding channels for the other types of injection.

The injected bodies are, in part, clearly satellites of underlying batholiths, but it is possible that many of them are due to the migration of hydrous magmas locally generated in the depths of a greatly metamorphosed terrane.

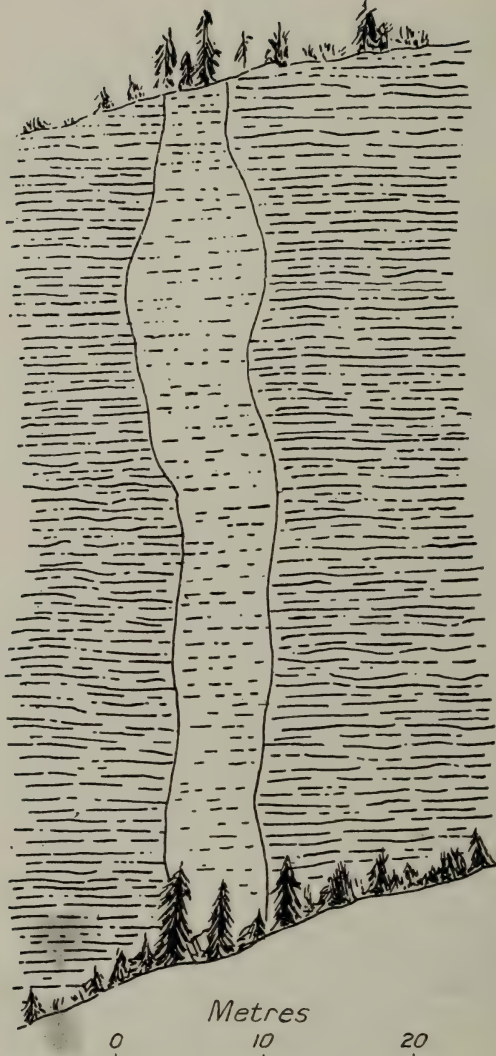
The principal petrographic types in these intrusions are: biotite granite (most abundant); hornblende-biotite granite; two-mica granite (rare); pegmatite and aplite (both very abundant); and orthogneisses corresponding to each of these magmatic species. Extended microscopic study shows that there is little mineralogical novelty; the rock types are duplicated in most of the 'Archean' tracts on the globe and are usually gneissic in structure.

The extraordinary prevalence of sills and other concordant injections is explained by the extreme fissility of the Shuswap sediments and greenstones. This feature is due to static metamorphism. As shown in the following section on structure, the dips of the Shuswap terrane are generally low. Though its rocks have passed through several periods of energetic mountain-building, their dips over large areas do not surpass 15° and their average dip is probably no greater than 35°. The metamorphism is essentially as far advanced where the strata lie horizontal as where they are dipping at angles of 60° to 90°.

Further, it seems highly probable that the fissility had attained nearly its present perfection before the Beltian system of rocks was deposited in the Shuswap terrane, and thus at an early date in the earth's history. The conditions for the metamorphism include: deep burial, with consequent development of "stress" in the vertical direction; and an abundant supply of interstitial water, such as that originally trapped in the sediments and volcanic beds. The completeness of recrystallization, which is much more striking than that visible in similar geosynclinal rocks of Cambrian or later date, implies that at least one other condition was here necessary. Hypothetically we may find it in a specially steep thermal gradient, controlling subsurface temperatures in pre-Beltian times. Field evidence thus leads to the suspicion that the earth was then notably hotter than it was later, when most of the known thick masses of sediments were deposited.



Schistose structure of typical orthogneiss in Shuswap terrane, illustrating static metamorphism. The hammer is about 32 cm. in length. Locality, Albert Canyon station.



Cliff section of aplitic dyke cutting paragneiss(?); Shuswap terrane at Clanwilliam. The dyke shows nearly horizontal schistosity, parallel to that in its country rocks; all have undergone static metamorphism since the intrusion of the dyke.

Strain-slip cleavage in talc schist of the Shuswap series, at Blind bay. The well developed low-dipping schistosity is due to earlier static metamorphism. Camera case about 7 cm. thick.

Whatever be the explanation, it is clear that the Shuswap series has not been seriously affected by dynamic metamorphism. The strata and most of the injected granites were completely or almost completely recrystallized while the strata lay nearly flat. In some localities the effects of dynamic metamorphism have been superposed on those due to previous static metamorphism. An example is illustrated on page 131. Similarly, thermal metamorphism produced by sills or batholiths is generally easy to distinguish from the prevailing regional type. Contact action has either coarsened the grain of the invaded formation or has developed hornfelses bearing minerals characteristic of plutonic contacts. The older members of the Shuswap series are, in general, more coarsely crystalline than the younger, partly because of deeper burial, but more because of the greater abundance of intrusions at the lower horizons.

BELTIAN SYSTEM.

Unconformably overlying the Shuswap terrane in the Selkirk mountains is a vast thickness of conformable, unfossiliferous sediments, for which as a whole the name, *Selkirk series*, has been adopted. The lower and greater portion of these beds is of pre-Cambrian age; the uppermost beds, as exposed in the railway section are referred, on stratigraphic evidence, to the Lower Cambrian. The group is clearly the northern continuation of the Belt series of Montana and Idaho. To the Pre-Cambrian portion of each series Walcott has applied the name 'Beltian' as a systemic designation and it will be adopted for present use.

In the railway section the Beltian is constituted of the following members.:

Columnar Section of the Beltian System in the Selkirk Mountains.

		Approximate Thickness. Feet.	Metres.
	Top, erosion surface.		
GLACIER DIVISION (*Selkirk series of Dawson*).	Ross quartzite (in part)....	2,500	762
	Nakimu limestone........	350	107
	Cougar formation (quartzite with metargillitic beds)	10,800	3,292
ALBERT CANYON DIVISION (*Nisconlith series of Dawson*).	Laurie formation (metargillite, often calcareous; with subordinate interbeds of limestone and quartzite; basal bed, gray limestone 15 m. thick)..	15,000	4,572
	Illecillewaet quartzite......	1,500	457
	Moose metargillite........	2,150	655
	Limestone (marble).......	170	52
	Basal quartzite...........	280	85
	Base, unconformity with Shuswap terrane.		
		32,750	9,982

In the railway section the *basal quartzite* is a greenish-gray, fine-grained metarkose, a massive to well-bedded, feldspathic rock of quartzitic habit, though strongly charged with films of sericitic mica. The original material was the somewhat washed sand due to the secular decomposition of the underlying Shuswap orthognesis. It will be described in greater detail in a following account of the geology about Albert Canyon station.

At its top the quartzite is interleaved with the lowest layers of the overlying *limestone*. This is a thin-bedded to thick-bedded, white to bluish marble, generally weathering to a pale buff colour. It is magnesian throughout, though some beds are more purely calcitic than others.

The *Moose metargillite* has been so designated from an older name of Albert creek, which enters the Illecillewaet river at Albert Canyon station. The middle part of this formation has not yet been found in satisfactory exposure

but the whole seems to be a fairly homogeneous argillite, now largely recrystallized by static metamorphism—a metargillite. All phases are charged with sericite, developed parallel to the bedding planes, and occasionally one finds thin beds glittering with coarser mica like a normal muscovite schist. The colour is generally gray, of a dark tint due to disseminated particles of carbon.

The *Illecillewaet quartzite* is hard, gray, massive to fissile, and relatively homogeneous except for thin intercalations of metargillite. Unlike the basal quartzite, it is poor in feldspathic material and evidently represents a more completely washed and assorted sediment.

In the monoclinal section between Albert Canyon and Ross Peak stations, the *Laurie formation* (named after the mining camp at the railway) is of most remarkable thickness. Measurement on the actual outcrops gave the following succession.

	Approximate Thickness.	
	Feet.	Metres.
Base of the Cougar formation.		
Gray, phyllitic metargillite..................	4,000	1,219
Quartzite..............................	650	198
Black to dark gray metargillite..............	500	152
Alternating beds of phyllite and quartzite.....	750	229
Black to dark gray, carbonaceous, often pyritous metargillite, with interbeds of blackish limestone..............................	9,300	2,835
Gray quartzite..........................	400	122
Black to dark gray, strongly carbonaceous metargillite, with numerous interbeds of blackish limestone..............................	3,500	1,067
Massive, light gray limestone................	50	15
Top of Illecillewaet quartzite.		
	19,150	5,837

There is no sign of important duplication by strike-faulting, though some thickening is represented in local crumples. Admitting all possible duplication suggested by the facts now in hand, this formation must be credited with a thickness of more than 15,000 feet (4,572 m.). On

Top of Cougar mountain, looking southeast; showing Cougar quartzite as typically developed in the Selkirk range.

account of the general uniformity of composition and habit, no satisfactory subdivision of the formation is yet feasible; because of their limited exposure in the railway zone, the quartzitic beds cannot be used for subdivision.

The *Albert Canyon division* of the Selkirk series is thus chiefly of metargillitic composition. The overlying *Glacier division*, more especially as it crops out on the western slope of the Selkirk range, is dominantly quartzitic.

Its most heterogeneous member is the *Cougar formation*, named from Cougar mountain, in which it is exposed on a great scale. In the monocline between Caribou creek and the Caves of Cheops (Nakimu), the formation shows the following general succession.

Columnar Section of the Cougar Formation.

	Thickness.	
	Feet.	Metres.
Conformable base of the Nakimu limestone.		
Gray, thin-bedded to thick-bedded quartzite, weathering rusty; with thin interbeds of phyllite and white quartzite; a few seamlets of crystalline limestone in the uppermost quartzite..............................	5,500	1,677
Conspicuous band of white, homogeneous, massive quartzite......................	300	91
Massive, light gray quartzite, interrupted by many bands of gray, quartzitic grit and coarse sandstone and by beds of dark gray, silicious metargillite; about 1,000 feet (305 m.) from the top, a thick band of massive white quartzite..................	3,000	915
Quartzitic and phyllitic, gray sandstone and fine conglomerate with metargillite. Near the middle of this zone, angular fragments of altered basaltic rock (bombs?) enclosed in an argillaceous (?)base were found........	900	274
Altered basaltic lava......................	50	15
Thick-platy to flaggy, sometimes phyllitic, gray quartzite..............................	1,050	320
Conformable top of Laurie formation.		
	10,800	3,292

East of the divide of the Selkirk range, the Cougar formation is, on the whole, thin-bedded and more argillaceous (originally) than in the section just detailed. The equivalent strata of the Rocky mountains—the Corral Creek formation and the lower part of the Hector formation—are still more argillaceous, consisting of gray, green, purple, and black metargillites with interbeds of rusty quartzite. (See p. 172). The rocks of this general horizon thus become finer-grained, less purely silicious, and more argillaceous as the section is followed from west to east. A similar variation characterizes the Rocky Mountain Geosynclinal rocks at the 49th Parallel section.

The *Nakimu limestone* is specially notable as being the most useful horizon-marker in the Selkirk and Purcell mountains. It is truly protean in lithological features, but one is seldom at fault in identifying it in the field. The Caves of Cheops (Caves of Nakimu) have been formed by solution and by the mechanical erosion of Cougar creek, as it follows for some distance a subterranean course in the formation. At that, most westerly, outcrop the formation is a light gray, fine-grained crystalline limestone. The rock is comparatively homogeneous, but carries disseminated sericitic mica in many beds. In the outcrops of the eastern Selkirks and of the Purcell mountains, the same gray type of limestone is interbedded with blackish, very carbonaceous limestone and with rusty-weathering, sandy or pebbly, dolomitic limestone. The thickness is quite variable—from as much as perhaps 600 feet (183 m.) at the Caves of Cheops to a few feet near Beavermouth. These differences are in part original; in part they seem to be due to squeezing-out during the uplift of the mountains.

The Nakimu limestone is conformably overlain by the thick *Ross quartzite* named from Ross peak, a mountain opposite Cougar creek at its confluence with the Illecillewaet river. The lower part of this formation is of Pre-Cambrian age; the upper part is probably to be assigned to the Lower Cambrian. All these admirably exposed beds are conformable not only with one another but also with the definitely Lower Cambrian Sir Donald quartzite above.

In the section between the Caves of Cheops and Rogers Pass station near the summit of the Selkirks, the Ross formation is relatively homogeneous, with composition as here indicated:

Columnar Section of the Ross Formation

	Thickness.	
	Feet.	Metres.
Conformable base of Sir Donald quartzite.		
Gray, rarely rusty, thick-bedded, compact quartzite, with interbeds of gray and brownish quartzitic sandstone and grit..........	1,200	366
Pale rusty-brown silicious phyllite or sericitic quartzite, carrying in the middle a 15-metre bed of gray quartzite....................	350	107
Gray quartzite, thick-platy and homogeneous, weathering gray and rusty; with interbeds of hard quartzitic grit and sandstone......	3,700	1,127
Conformable top of the Nakimu limestone.	5,250	1,600

In the grand exposures along the northwestern edge of Beaver River valley the Ross formation weathers more uniformly rusty but is still quartzitic; this section shows an approximate thickness of 5,000 feet (1,524 m.). At the summit of the Dogtooth mountains, the formation is more argillaceous, while retaining its deep rusty colour and numerous bands of fine quartz conglomerate or grit so characteristic in the Selkirks. It is correlated with the shaly to sandy beds in the upper part of the Beltian-Hector formation and in the Lower Cambrian Fairview formation —both exposed in the Bow River valley of the Rocky mountains. Here again the geosynclinal rocks in the east are more argillaceous than those contemporaneously deposited in the west.

Cambrian System.

At the summit of the Selkirk range the Ross quartzite passes gradually upwards into the *Sir Donald formation.* This is a very homogeneous mass of quartzite, much like

Summit of the Dogtooth range, looking east from a peak near head of Quartz creek. Slopes underlain by the Ross formation as typically developed in the Purcell mountains.

the more silicious phase of the Ross but weathering with a gray, rather than a rusty, surface. On fresh fractures the Sir Donald quartzite varies in the colour from white through pale gray and greenish-gray to dark gray, rarely rusty. It is characteristically thick-bedded. Like the Ross formation it is often feldspathic and is charged with numerous lenses of quartz-feldspar grit and fine quartz-feldspar conglomerate. Near the base there is a 53-metre band of pale-rusty to gray quartz-sericite schist.

Summit of Mt. Tupper from Tupper Crest, showing characteristic habit of the Sir Donald quartzite. Photograph by Howard Palmer.

The Sir Donald quartzite forms most of the highest summits of the Selkirk mountains and is terminated above by the present erosion surface. It has yielded no fossils but clearly represents the fossiliferous Lake Louise and St. Piran series of the Rocky mountains. The Lower Cambrian Mt. Whyte formation of the Rockies may also be correlated, tentatively, with the upper beds of the Sir Donald quartzite.

The general correlation of formations in the Selkirks and Rockies may be stated as follows:

	SELKIRK MOUNTAINS.	Thickness. Feet.	Thickness. Metres.	ROCKY MOUNTAINS.	Thickness. Feet.	Thickness. Metres.
	Erosion surface.			*Conformable base of the Middle Cambrian.*		
Lower Cambrian	Sir Donald quartzite.........	5,000+	1,524+	Mt. Whyte formation..........	390	119
				St. Piran formation............	2,705	823
				Lake Louise formation..........	105	32
	Ross quartzite (upper part)...	2,750	838	Fairview formation.............	600	183
Beltian	Ross quartzite (lower part)...	2,500	762	Hector formation (upper part)...	630	192
	Nakimu limestone...........	350+	107+			
	Cougar formation (in part)	10,800	3,292	Hector formation (lower part) ..	3,960	1,206
				Corral Creek formation.........	1,320	403
				Base concealed.		

With the exception of the Sir Donald and upper-Ross quartzites, Cambrian strata are absent in the railway section west of the Rocky Mountain trench. The enormous development of the Cambrian in the Rocky mountains was demonstrated by McConnell and Dawson. More recent studies by Walcott and Allan have led to its detailed subdivision, as here summarized.

Columnar Section of the Rocky Mountain Cambrian.

	Formation.	Thickness. Feet.	Thickness. Metres.
Upper Cambrian	Ottertail limestones.	1,725	526
	Chancellor shales, etc.........	4,500	1,372
	Sherbrooke limestones........	1,375	419
	Paget limestones.............	360	110
	Bosworth limestones, etc......	1,855	565
Middle Cambrian	Eldon limestones............	2,728	831
	Stephen limestones, etc.......	640	196
	Cathedral limestones.........	1,595	486
Lower Cambrian	Mt. Whyte shale. etc.........	390	119
	St. Piran quartzitic sandstone	2,705	824
	Lake Louise shale............	105	32
	Fairview sandstone, grit, etc..	600	183
		18,578	5,663

On pages 174ff. will be found Dr. Allan's summary description of these formations.

Ordovician System.

Ordovician strata are represented at the railway section only within the limits of the Rocky mountains and the floor of the Rocky Mountain trench. These beds once extended over the site of the Purcell range and over much

of the eastern Selkirks but have there been completely denuded. It is highly probale that the western half of the Cordillera was a land surface during the Ordovician.

In our section the system is composed of the *Goodsir shales* and the *Graptolite shales*. Dr. Allan credits them with respective thicknesses of 6,040 feet (1,841 m.) and 1,700 feet (518 m.). His account of them appears on pages 179-181.

Silurian System.

The Silurian rocks of the section seem to have had the same general distribution as the Ordovician shales. To the younger system belong the *Halysites beds*, a formation named by McConnell and described on page 181 by Dr. Allan, who estimates the thickness of the formation at 1,850 feet (563 m.)

Devonian System.

Sediments of Devonian age in the railway section are also confined to the Rocky mountains. The *Intermediate limestone*, named by McConnell and described by Dr. Allan on page 181 has a thickness estimated at 1,800 feet (548 m.) or more. In the Sawback range it is conformably underlain by the unfossiliferous *Sawback formation*, 3,700 feet (1,128 m.) thick. This is certainly post-Cambrian but its exact age cannot now be declared. (See page 182.)

Mississippian System.

The strata formerly mapped as Carboniferous in the Rocky mountains of our section have recently been shown by Shimer to be partly Mississippian and partly Pennsylvanian in age.* The former system is represented in the *Lower Banff limestone* (thickness, 1,500 feet or 457 m.) and the overlying *Lower Banff shale* (thickness, 1,200 feet or 366 m.), both named in McConnell's original report. [**2**, p. 17]. Some details concerning these will be found on page 182.

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*H. W. Shimer, Summary Report, Geo. Surv. Can. 1910, p. 147. Since this passage was written Dr. Shimer has concluded from palaeontological evidence that at least part of the Lower Banff limestone is Devonian.

Pennsylvanian System.

In the Rocky mountains of our section the Pennsylvanian system includes the *Upper Banff limestone*, and the overlying *Rocky Mountain quartzite*, with estimated or measured thicknesses of 2,300 feet (701 m.) and 800 feet (244 m.) respectively. Dr. Allan's account of them is given on page 183.

Pennsylvanian rocks show yet greater thickness in the western half of the Cordillera, where they represent the the oldest Paleozoic strata known in the railway section. They have been named by Dawson the *Cache Creek group*, his own description may be quoted in abstract. Writing of the group as a whole he says:

"The lower division consists of argillites, generally as slates or schists, cherty quartzites or hornstones, volcanic materials with serpentine and interstratified limestones. The volcanic materials are most abundant in the upper part of this division, largely constituting it. The minimum volume of the strata of this division is about 6,500 feet. The upper division, or Marble Canyon limestones, consists almost entirely of massive limestones, but with occasional intercalations of rocks similar to those characterizing the lower part. Its volume is about 3,000 feet.

"The total thickness of the group in this region would therefore be about 9,500 feet, and this is regarded as a minimum. The argillites are generally dark, often black, and the so-called cherty quartzites are probably often silicified argillites. The volcanic members are usually much decomposed diabases or diabase-porphyrites, both effusive and fragmental, and have frequently been rendered more or less schistose by pressure . . . .

"In the southern part of British Columbia, the Cache Creek group shows some evidences of littoral conditions toward the west slopes of the Gold [Columbia and adjacent] ranges, probably indicating the existence of land areas there." [**5**, p. 70].

Travelling westward over the railway, the Cache Creek rocks first appear in a long section east of Kamloops on the South Thompson river. (See page 231). The group originally covered all, or almost all, of the western half of the Cordillera and has been found to have a thickness of at least 6,800 feet (2,073 m.) in the Chilliwack canyon, near Vancouver. [**11**, Part I, p. 514, and Part II, p. 559].

Dr. N. L. Bowen's Agassiz series, noted on page 258, is probably part of the same great geosynclinal.

Permian System.

As yet rocks of Permian age are known only in the Rocky Mountain portion of the railway section. There Shimer has shown that the *Upper Banff shale* is to be so dated. With a thickness of 1,400 feet (427 m.) it lies conformably upon the Rocky Mountin quartzite. Dr. Allan summarizes the character of the formation on page 183.

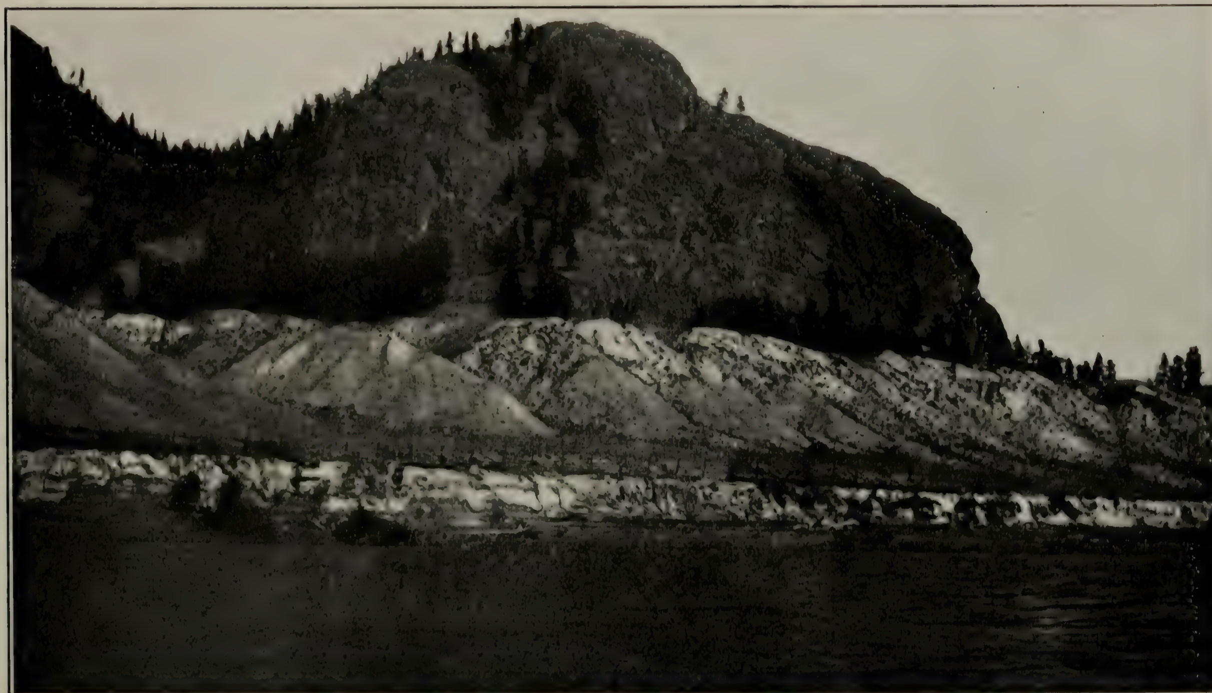
Triassic System.

No formations referable to the Triassic are known in the railway section across the Rocky, Purcell, Selkirk, and Columbia Mountain ranges. On the other hand, Triassic rocks are extensively developed in the western half of the Cordillera, where they have had a volume comparable to that of the Cache Creek phase of the Pennsylvanian. Dawson proved the lower Mesozoic age of his *Nicola group*, which still covers large areas in the Belt of Interior Plateaus. The greater part of this group is constituted of basic volcanic rocks (chiefly basalts and diabases) with thin interbeds of limestone carrying Triassic fossils. The upper members of the group are referred to the lower Jurassic. Dawson estimated the total thickness at the Thompson river to be 13,500 feet (4,115 m.), of which at least nine-tenths represents volcanic rock. On account of the extraordinary massiveness of the lavas, it has as yet proved impossible to make a trustworthy columnar section for the group.

Thick fossiliferous shales of Triassic age have been found in the Cascade range just south of the railway at Harrison Mills, 61 miles (98 km.) from Vancouver. The Boston Bar argillites, occurring between Lytton and Hope, have recently been shown by Dr. Bowen to be of Mesozoic age and may also belong to the Triassic.

Jurassic System.

Excepting those noted in the Nicola group, no Jurassic fossils have been discovered in our section west of the



Characteristic outcrop of Triassic (Nicola) basalts near Ducks station. The terrace is composed of the white Thompson River silts.

Rocky mountains. In that range itself the rock system is represented by the *Fernie shale*, with a thickness of 1,500 feet (457 m.). Its description is briefly given by Dr. Allan on page 184.

Cretaceous System.

Following the orogenic disturbances near the close of the Jurassic, sedimentation in our section became restricted to relatively narrow geosynclines or zones of overlap. A thick mass of Cretaceous strata was deposited in a down-warp along the eastern limit of the Cordilleran area. Other local geosynclinal prisms were developed near the line of the present Pacific coast. The stratigraphy of each of these two sedimentary provinces needs separate treatment.

In the eastern Rockies, west of Bankhead, beds lying conformably on the Jurassic Fernie shale and all of Lower Cretaceous age, have been subdivided into three formations: the *Lower Ribboned sandstone*, the *Kootenay Coal measures* and the *Upper Ribboned sandstone*. Their respective thicknesses are approximately: 1,000 feet (305 m.), 2,800 feet (853 m.), and 550 feet (168 m.). On page 185 is to be found Dr. Allan's description of the formations. The railway section does not give the full thickness of this geosynclinal, to which Dawson has credited a value of more than 11,000 feet (3,353 m.).

Six hundred kilometres (370 miles) farther west, Lower Cretaceous rocks again appear in the section. They cover two principal areas: one at Ashcroft, the other following the Fraser valley north and south of Lytton. Both groups of rocks are doubtless remnants of a single geosynclinal, once covering part of the Belt of Interior Plateaus as well as part of the Coast Range region. A still greater remnant has been mapped at the 49th parallel section under the name Pasayten series, of which the Lower Cretaceous members alone have a thickness of about 7,000 metres.

The erosion remnants at Ashcroft and Lytton consist of highly indurated sandstones, argillites and conglomerates. "The sandstones are most commonly of greenish-grey colours, passing on one hand into coarse, distinctly green rocks, largely composed of arkose materials derived from the older [Paleozoic and Triassic] greenstones and [late Jurassic] granites; on the other, into fine-grained blackish sandstones, which grade down perceptibly into argillites

of the same colour." [**4**, p. 151]. Owing to structural complication, no attempt at a detailed section of the Cretaceous in either of the areas has yet been successful. Dr. Drysdale estimates the minimum thickness of the Ashcroft remnant at 5,000 feet (1,524 m.), while Dawson indicated a value of 7,000 feet to 10,000+feet (2,133 to 3,048+m.) for the Fraser valley Cretaceous. A partial section in the latter area (Jackass Mountain series) is given by Dr. Bowen on page 258. Mr. Camsell also refers certain quartz porphyry flows found west of Hope station to the Lower Cretaceous. (See page 273.)

EOCENE SYSTEM.

In our section rocks of Tertiary age are entirely confined to the western half of the Cordillera. So far as known, they have originated in volcanic action or in fresh-water sedimentation, though it is possible that the Eocene strata of the Pacific coast are partly marine.

The formations assigned to the Eocene are: the sedimentary *Coldwater group*; and the sedimentary *Puget group*. These are local formations and their mutual relations have not been fully determined.

The Coldwater group, named and mapped by Dawson, is probably younger and includes conglomerate, sandstone, shale and coal accumulated in the valleys formed during and after post-Cretaceous mountain-building. Penhallow's recent study of the fossil floras contained in these beds as mapped by Dawson refers at least part of them to the Eocene proper [**6**, p. 106]. Dawson estimated the local maximum thickness of the Coldwater beds to be about 5,000 feet (1,524 m.)

Like the other Eocene groups, the Puget beds—sandstones, conglomerates and shales with thin coal beds—are in unconformable relation to the Cretaceous. They attain very great thickness in Puget sound. In the railway section the group is truncated by the existing erosion surface; the remnant of the Tertiary sediments on the lower Fraser has an observed thickness of about 3,000 feet (914 m.)

OLIGOCENE SYSTEM.

The Belt of Interior Plateaus is widely covered with lavas mapped by Dawson as the 'Upper Volcanic Group'

and referred by him to the Miocene, as then defined for western stratigraphy [**5**, p. 80]. Dr. Drysdale is still inclined to regard the lavas as of lower Miocene age (see page 243), though recent paleontological and stratigraphical work by Lambe and Penhallow seems to show that these rocks—hereafter called the *Kamloops Volcanic group*—should be assigned to the Oligocene. The fossils in question, fish remains and plants, have been found in the *Tranquille beds*, a series of local, tuffaceous, partly fresh-water sediments intercalated near the base of the Kamloops volcanics.

The Tranquille beds are estimated to have a thickness of 1,000 feet (305 m.); the Kamloops lavas, a maximum thickness of at least 3,000 feet (914 m.), with an original average thickness probably greater than 2,000 feet (610 m.)

The Kamloops volcanics are the youngest bed-rocks known in the railway section. Up to the present time no Miocene or Pliocene sediments have been found there. Within sight of the railway, at Mission Junction, is the Pleistocene-Recent volcano, Mt. Baker.

PLEISTOCENE SYSTEM.

The Quaternary formations are briefly noted at various appropriate places in this guide-book.

GENERAL STRUCTURE.

The sedimentary rocks of our trans-montane section belong to three geological provinces.

The Beltian and Lower Cambrian strata of the Selkirk mountains and their equivalents in the Rocky mountains, with the conformable formations of Middle Cambrian to Permian age, together form a single mass of rocks. In the Selkirks there is perfect conformity between the Lower Cambrian and Beltian systems ; in the Rockies their relation is reported to be that of conformity at some contacts, and that of moderate unconformity at others. (See page 172). There is no thorough-going unconformity in this gigantic series. It is, in fact, best regarded as a single geosynclinal prism of the first order. The maximum thickness of strata here represented is, perhaps, greater than that of any other measured group of sediments. With varying

strength and complication, including the presence of local unconformities, this prism is already known to extend from Colorado to Western Alaska. Throughout the length of the Cordillera in Canada and Alaska as well as in the United States proper, the Rocky mountains are almost wholly composed of the prism; hence this gigantic unit has been named the *Rocky Mountain Geosynclinal.* On its back have been deposited, unconformably, local geosynclinals of late-Mesozoic and of early Tertiary dates. These have major axes parallel to that of the older, greater prism and parallel to the general axis of the Cordillera. The whole, compound assemblage of sediments forms the *Eastern Geosynclinal Belt* of the Cordillera.

2. On the other hand, the chief sedimentary rocks of the Coastal system of mountains—including the Coast range of Alaska and British Columbia, the Vancouver range, the Olympic mountains, the Cascade range, and the Sierra Nevada of California—are of Carboniferous (Pennsylvanian), Triassic, and Jurassic age. These beds were deposited in a broad, very long zone of subsidence. The sedimentation was not continuous; there are local unconformities in the series. Yet, as a whole, this deposition was long-continued and on a regional scale within the geographical zone described. Since, moreover, the clastic strata were deposited in Pacific water and represent detritus largely from the Eastern Belt, the whole complex prism may be called the *Main Pacific Geosynclinal.* After a late-Jurassic orogenic revolution affecting this entire prism, local areas of the now deformed zone were downwarped and received heavy loads of sediment in the form of Cretaceous and early Tertiary geosynclinal prisms. These, along with the much greater Main Pacific Geosynclinal, form the *Western Geosynclinal Belt* of the Cordillera.

3. Between the two belts, on the line of the Canadian Pacific Railway, lies the *Shuswap Terrane*, the third and last of the major sedimentary provinces. Its rocks are of Pre-Cambrian (pre-Beltian) age. In our section, the eastern limit of the terrane is at Albert Canyon on the western slope of the Selkirks; its western limit is a few miles below the outlet of Little Shuswap lake, in the Belt of Interior Plateaus.

Along the railway, the Rocky mountains form a synclinorium, broken by numerous faults and by occasional zones of mashing. The eastern limb of the synclinorium

is thrust at least 11 kilometres (7 miles) over somewhat deformed Cretaceous strata. The western limb terminates in a master-fault running in the general line of the Rocky Mountain trench. This fault, with downthrow of at least 5 kilometres (3 miles), is likewise the eastern limit of a second synclinorium forming the Purcell mountains and the eastern part of the Selkirks. The western limit of this

Looking south from Mt. Tupper to Mt. MacDonald and Mt. Sir Donald (background), showing part of the summit syncline of the Selkirks as shown in the Sir Donald quartzite forming the great escarpment. Photograph by Howard Palmer.

broad flexure is a relatively simple monocline extending from the summit of the Selkirks to the primary unconformity at Albert Canyon.

Each synclinorium is unsymmetric, with older strata exposed on the western edge than on the eastern. This is particularly striking in the Selkirks, where the Shuswap terrane is exposed on the west, below the basal beds of the Beltian system, while the Cambrian quartzites appear at the surface not far west of the fault in the Rocky Mountain trench. The maximum amount of uplift registered in the railway section has charactertized the eastern part of the

Drag folds in the Cougar quartzite near head of Cougar creek, Selkirk range. Cliff shown is about 15 m. in height.

Shuswap terrane, where the younger sediments of pre-Beltian age have been eroded away.

While the Shuswap sediments attained the thickness of a first-class geosynclinal, no clear hint has been forthcoming as to the geographical source of their clastic material, nor as to the direction of the major axis of this prism. There is nothing to show that the subsiding trough had the Cordilleran elongation which has been so characteristic of the post-Shuswap geosynclines. In two leading respects the pre-Beltian terrane contrasts structurally with the younger geosynclinals.

The Shuswap series is less deformed than any of the overlying series, up to and including the Triassic. In the Selkirks and Interior Plateaus the average dip calculated for the beds of the oldest terrane is no greater than 35°, while the averages for large, typical areas of the Albert Canyon division and Glacier division of the Selkirk series, for the Carboniferous, and for the Nicola series, are, respectively, about 38°, 59°, 73°, and 64°. This is true, though the Shuswap terrane obviously underlay these younger formations when they were passing through several orogenic revolutions. Today, the Shuswap rocks in numerous areas each many square miles in extent are nearly horizontal, while adjacent Carboniferous strata are intensely folded. It appears necessary to believe that the earth-shell which has here transmitted the mountain-building thrust had a depth of only a few kilometres; and that this shell was sheared over its basement of Shuswap rocks.

The second noteworthy feature is the general failure of the Shuswap strata to show the Cordilleran trend characteristic of all the younger formations. The prevailing strike of the basement rocks is about N. 70° E., and thus nearly at right angles to the general Cordilleran strike in this latitude. Quite locally the older rocks have been gripped in a post-Carboniferous plication and show Cordilleran strike; such exceptions do not invalidate the general rule. One is reminded of the prevailing E.—W. to N. 60° E. strikes in the Pre-Cambrian rocks of Lake Superior and eastward thereof, in the Canadian Shield. Is this agreement of structural trends in the two Pre-Cambrian areas fortuitous?

As already stated, the detailed structure of the Shuswap terrane offers a host of unsolved problems. In general,

the deformation of the bedded rocks seems to have consisted in warping and normal-faulting, especially the latter. The extremely abundant sills and other intrusive bodies have suffered nearly as much deformation as the invaded sediments.

The Western Geosynclinal Belt is structurally the most complex of the three principal provinces. All of its bedded formations, from the Carboniferous to the Cretaceous inclusive, are more or less intensely folded. The thick Carboniferous group has been specially affected by close-folding and mashing, with resulting turmoil in most of the Carboniferous areas.

Rocks of the Beltian to the Mississippian, inclusive, are only locally represented in this province, which except for limited areas was clearly a region of erosion during that long period. In our section the oldest known Paleozoic strata are Carboniferous (Pennsylvanian) in date. These lie unconformably upon the Shuswap terrane. A second unconformity is well exposed between the Pennsylvanian limestone and the Triassic near Kamloops. A third exists at the base of the Lower Cretaceous; a fourth at the base of the older Tertiary (Eocene?) geosynclinal deposits of the Strait of Georgia and Puget sound. An unconformity is registered at the base of the Oligocene in the Interior Plateaus and it probably corresponds to a deformation of post-Eocene date. A sixth unconformity is, of course, seen at the contact of the Pleistocene deposits with older formations.

NOTE ON THE IGNEOUS BODIES.

The sedimentary rocks of the Eastern Belt are, in our section, very seldom interrupted by igneous masses. The remarkable Ice River intrusion (see page 185) and the contemporaneous lavas in the Cougar formation (see page 136) are the only important eruptions observed in the railway zone between the Great Plains and the heart of the Selkirk range. On the other hand, the Western Belt shows not only a much larger number of unconformities, but also an incomparably greater amount of igneous activity.

Following the rule illustrated throughout the world, the downwarping of the western geosynclines has been

Looking north over the South Thompson river, from Campbell's ranch, 9 km. west of Ducks station. The creek bed in the middle of the view is located on the plane of unconformity between Pennsylvanian limestone (left, light-coloured outcrops) and Triassic conglomerate and basalt (right, dark-coloured outcrops).

accompanied by some contemporaneous volcanic action. Surface lavas of both central-eruption type and fissure-eruption type are found in the Pennsylvanian, Triassic, Eocene, and Oligocene downwarps of the Western Belt. In our section the volcanics of the Triassic and Tertiary are much thicker than the sediments of their respective dates. The Western Belt is, in fact, a volcanic province of the first order, whether considered as to volume of extravasated material, as to persistence of eruptivity in geological time, or as to area of country still covered by the lavas. The great cone of Mt. Baker, south of the railway at Mission Junction, represents Pleistocene-Recent vulcanism.

Batholithic intrusions are very rare in the Eastern Belt and are entirely absent in the railway section. They cut the Paleozoic strata of the Western Belt on a scale unmatched elsewhere in the world except, perhaps, in the Pre-Cambrian terrane of Eastern Canada, Fennoscandia, etc. The composite Coast Range batholith of British Columbia and Alaska is about 1200 miles (1930 km.) in length, with an average width of nearly 90 miles (144 km.). The railway section crosses it in the stretch between Lytton and Vancouver. It is composed of granodiorite and quartz diorite, with diorite, biotite granite, syenite, and allied types. There is clear evidence of successive intrusion but it is agreed that the general date of irruption for the greater part falls in the period from the latest Jurassic to the early Cretaceous. In our section the late Jurassic is the preferred date. Yet it is probable that this batholith, like those in Washington State and in the Kootenay district of British Columbia, received large increment or else batholithic replacement in post-Cretaceous time. In the railway section itself such Tertiary batholiths have not yet been proved and the earlier date is generally accepted for many smaller batholiths east of the Fraser river as well as for the Coast Range body. Some of the little sheared granitic masses cutting the western part of the Shuswap terrane are tentatively referred also to the late Jurassic.

These various bodies illustrate again and again the cross-cutting and apparently bottomless relations of true batholiths. The main contacts and the attitude of roof-pendants are eloquent in favour of the replacement theory of origin and strongly oppose the "laccolithic" theory. Evidence on this fundamental matter has been collected by: Clapp

in Vancouver Island; by Dawson, Bowen, Camsell, Le Roy, Bancroft and Daly in the Coast range; and by Daly in the Belt of Interior Plateaus. Their conclusions agree with many recent results of study in the Alaskan and United States portions of the Western Belt.

GENERAL HISTORY.

The earliest event demonstrated in the rocks of our section is the long-continued erosion of a silicious(granitic or gneissic) land surface older than the Shuswap series. No actual representation of this ancient mass has been discovered, but its existence is inferred from the abundant development of clastic, sandy and argillaceous beds of Shuswap age in south-central British Columbia. This deposition continued long, though it was often interrupted by the precipitation of limestone (e.g., Sicamous formation.) Clastic and chemical sediments together formed a geosynclinal mass several kilometres in thickness. Within it there is no sign of unconformity. Toward the close of this epoch of sedimentation and before any notable deformation of the geosyncline, basic lavas broke through the earth's crust and buried the older deposits very deeply (Adams Lake greenstone).

The lower members of the series were drastically affected by static metamorphism, whereby sediments and lavas became converted into true crystalline schists—metargillites, phyllites, and other mica schists, quartz-sericite schists, calc-schists, chloritic and uralitic schists. Excessive fissility essentially parallel to bedding-planes was thus imposed upon the Shuswap series. It was then invaded by granitic magma which sent off-shoots into the easily split schists, in the form of innumerable sills, laccoliths, and dykes, on a scale seldom matched. The plutonic invasion took place by successive stages, so that older intrusions are cut by younger. As so often the case, the youngest magmas were aplitic or pegmatitic in habit. This salic material forms countless small bodies in the Shuswap terrane. Practically all these intrusions, except the youngest aplites and pegmatites, were themselves subjected to static metamorphism, converting them into orthogneisses. The resulting schistosity, generally well developed, is sensibly parallel to the stratification planes of the adjacent sediments.

These intrusions must have been accompanied by some deformation of the Shuswap series. In any case, the plutonic invasion was followed by erosion which bit deeply into the new terrane—a process long continued, implying great uplift above baselevel. The uplift was, however, not accomplished as an incident of intense folding. The average dip of the Shuswap rocks is today low. It must have been lower in pre-Beltian time, for the planes of schistosity and sill-contacts of the Shuswap are nearly parallel to the basal beds of the Beltian system at Albert Canyon and have been upturned to angles of 45° to 55° since Beltian time. The pre-Beltian deformation may well have developed a broad geanticline accidented by slightly tilted fault-blocks. Their average strike possibly corresponded with the present dominant strike of the terrane, namely, about N. 70° E.

The first sediments formed by the erosion of the Shuswap terrane have nowhere been identified. A great mass of it had already been removed before the region about Albert Canyon was depressed below sea and was covered by the lowest exposed bed of the Beltian system. That bed was a little-washed arkose sand, in mineralogical composition differing but little from the shell of secular weathering on the Shuswap orthogneiss beneath. It is probable that this unconformity represents the preliminary erosion of the Shuswap bedded series at this locality.

With the geanticlinal uplift of the pre-Beltian terrane, the oldest known structure visibly paralleling the existing Cordilleran axis was developed. The zone roughly represented by the Western Geosynclinal Belt now became a land mass and the zone represented by a large part of the existing Eastern Belt become an elongated basin of deposition (largely, if not wholly, marine in our section). The floor of the basin slowly subsided and upon it the Rocky Mountain Geosynclinal was accumulated. More or less continuously, from the beginning of the Beltian to the close of the Mississippian, this prism increased in thickness; during the Middle Cambrian it was greatly widened by marine transgression far to the eastward, if not to the westward, of the initial shore-lines. Detailed study of the sediments shows that their clastic materials, even as far east as the Front range of the Rockies, were largely derived from the land on the west, though a small proportion

was washed into the geosyncline fron land masses located in the longitudes of Montana and Wyoming.

In Arizona, Colorado, and elsewhere in the United States, the early Cambrian was a time of erosion following local deformation in the Rocky Mountain Geosynclinal area; and in the late Middle Cambrian a re-submergence, contemporaneous with the marine transgression elsewhere, restored conditions of sedimentation in the zone. In British Columbia and Alberta, however, there appears to be perfect conformity throughout the Cambrian. Opinions differ as to the existence of an erosional break at the base of the Lower Cambrian in the Rockies. Walcott has announced the existence of an unconformity in the rocks of the Bow valley but later observations by Dr. Allan and by the present writer indicate that the break at this horizon must in any case be local and does not represent a long interval of time.

As yet it is impossible to locate the line of maximum thickness for the geosynclinal. In the railway section the Beltian and Lower Cambrian strata grow thinner as they are followed eastward into the Rocky mountains, where the Middle and Upper Cambrian strata have their greatest known strength.

Next to the clastic material won from the adjacent lands, the most abundant constituent of the Rocky Mountain Geosynclinal is carbonate, chiefly limestone with some true dolomite. All of the pre-Ordovician carbonate-rock and most of the younger limestone and dolomite seems to be best explained as chemical precipitates. The total of the maximum thicknesses recorded for the carbonate rocks is more than 6,000 metres (20,000 feet).

Though contemporaneous vulcanism is recorded in this great prism at various horizons of the 49th Parallel section as well as elsewhere in the United States, it has added very little to the bulk of the geosynclinal at the Canadian Pacific section. So far as now known, the only occurrences of lava are those found in the Beltian Cougar formation.

In the Pennsylvanian (Carboniferous) period the geosyncline was enlarged both eastward and westward on a scale probably surpassing the marine transgression of the Middle Cambrain. Pennsylvanian sediments, chiefly limestone, were laid on the prism and in yet greater thickness limestones, shales, and more silicious beds were

now deposited in the Western Belt, which for the most part had so long remained above sea. The exact sources of supply for this fragmental detritus can not be fully determined. It is possible that islands of the Shuswap rocks still remained, and probable that parts of the Rocky Mountain Geosynclinal were upwarped, so as to suffer erosion during the Pennsylvanian. We know more definitely that some of the sedimentary matter in these rocks of the Western Belt was derived from the erosion of contemporaneous volcanoes. Great eruptions of basalt and basic andesite were widespread in the Western Belt during this period.

The Permian period has left no record of rock formation in the Western Belt but seems to be represented by continued deposition in the Eastern Belt (Upper Banff shale, 1,400 feet; 427 m. thick).

West of the Shuswap Lakes region the Pennsylvanian strata were at least locally subjected to moderate deformation, followed by erosion. These events anticipated the deposition of the Triassic shales and limestones, among which exceptionally heavy flows and pyroclastic masses of basalt were erupted. This vulcanism was widespread in the Western Belt, from Alaska to California. In British Columbia it took the form of heavy fissure eruptions with subordinate central eruptions. Few lava formations are as massive as the extensive and very thick basalts of the Nicola group. It is not certain that Jurassic sediments are represented anywhere in the railway section of the Western Belt. Hence the history of the Jurassic period is here obscure. From the analogy of other regions, particularly California, it is concluded that this part of the belt was strongly folded during the closing stage of the Jurassic.

In the Eastern Belt the Paleozoic era was closed by a broad upwarping, by which the sea was largely withdrawn from the Rocky Mountain geosyncline. It is probable that at least the western half of this belt in our section has been out of water ever since and that conditions of erosion there prevailed in the early Mesozoic. The upper Jurassic of the eastern foot-hills is conformable with the Cretaceous of the Great Plains and, like the latter, was probably in piedmont relation to the Cordillera Eastern Belt. The late Jurassic orogeny, so powerful in the Western Belt, did not seriously deform the Paleozoic

strata of the Rocky mountains; upon those the Jurassic and Cretaceous lie with apparent conformity. In the general absence of Mesozoic sediments in the Middle ranges of British Columbia, it is a delicate, still unsolved problem as to how far the western part of the Eastern Belt was mountain-built during the Jurassic. Perhaps the information will be found along the new Grand Trunk Pacific Railway line.

The late Jurassic folding in the Western Belt was immediately followed by granitic intrusion on a grand scale, whereby the enormous Coast Range batholith was outlined, if not largely completed. Many smaller batholiths and stocks were simultaneously intruded into the older rocks of Vancouver island and of the broad tract between the Coast range and the Selkirks.

From that time to the present both Eastern and Western belts of the Cordillera have witnessed subaerial erosion. Near the line of the present Pacific shore and also in the eastern foot-hill zone of the Rockies, local geosynclinals of great depth were formed in the Cretaceous. Examples are: the Pasayten geosynclinal, stretching from west-central Washington to and beyond the Fraser valley at North Bend and Lytton; the Queen Charlotte geosynclinal, west of the Coast range; and the Crowsnest geosynclinal of the Eastern Rockies. Sediments of both Lower and Upper Cretaceous age occur in these local downwarps of Cordilleran trend.

With the completion of the thick Cretaceous prisms, the conditions were ripe for renewed mountain-building and the Laramide revolution deformed most of the Canadian Cordillera. As in the more limited Jurassic revolution, the major thrusts were directed from the Pacific side but they were now, for the first time since the pre-Beltian period, of pronounced effect at the extreme eastern limit of the Eastern Cordilleran Belt. All observers agree that the major deformation of the Rocky Mountain Front ranges took place at this time. Opinions differ as to the date of the great overthrust by which those ranges have advanced outwards, over the Great Plains. Willis has postulated a mid-Tertiary date for the Lewis thrust at the International Boundary, but the present writer is inclined to regard it and the similar thrust in Alberta as incidents of the Laramide revolution [**6**, p. 340; and **11**, Part I p. 94].

Thus, at the dawn of the Tertiary the Cordillera was developed with full vigour of mountainous relief. Its volume in British Columbia, measured above sea level, was then probably at its maximum. Its general history is henceforth one of erosion coupled with intermittent vulcanism of great intensity and with diastrophic movements which were of great importance but of an order less than the revolutionary. In the absence of a widespread sedimentary record in the mountain chain, it is difficult to state Tertiary events in an orderly, quantitative way. Long chapters in the Tertiary history can only be written in the future, after modern physiographic methods have been applied in the as yet unmapped portions of British Columbia.

In the Canadian Pacific section no marine sediments of Tertiary age have been definitely reported. The Eocene geosynclinal of Puget sound was doubtless continued into the region of the Strait of Georgia and lower Fraser valley; but this irregular prism represents an intermont basin, in which much of the deposition was subaerial or in fresh or brackish water. There resulted one of the thick stratified masses necessarily developed in Eocene basins from the wasting of the new, vigcrous mountain chain. It is probable that the Belt of Interior Plateaus saw, in this period, a moderate amount of local volcanic action, paralleling the greater Eocene eruptions of Central Washington and of the Coast region. The eastern Cordilleran Belt carries no rocks of this period, which was apparently occupied throughout by erosive activity.

The Oligocene continued this erosion across the entire chain, but was marked in the Western Belt by long-continued emission of basalts, chiefly of the fissure-eruption type. This vulcanism involved much disturbance of drainage system. Local basins were formed and became filled with gravels, sands and muds, bearing fresh-water fossils (Tranquille group).

The Western Belt became affected by moderate orogenic movement, whereby the Oligocene lavas and sediments were locally upturned, sometimes to vertical position. This deformation is not yet accurately dated, but may prove to be of late Oligocene date. Though the local upturning was so pronounced, the Tertiary lavas of British Columbia were, in general, little disturbed from their original, flat attitudes, and it is reasonable to suppose that similarly

large surfaces underlain by non-volcanic rocks were not greatly deformed.

The Miocene was a time of general erosion across the entire Cordillera at our section.

The Cordilleran topography at the beginning of the Pliocene was evidently highly complex in origin and of

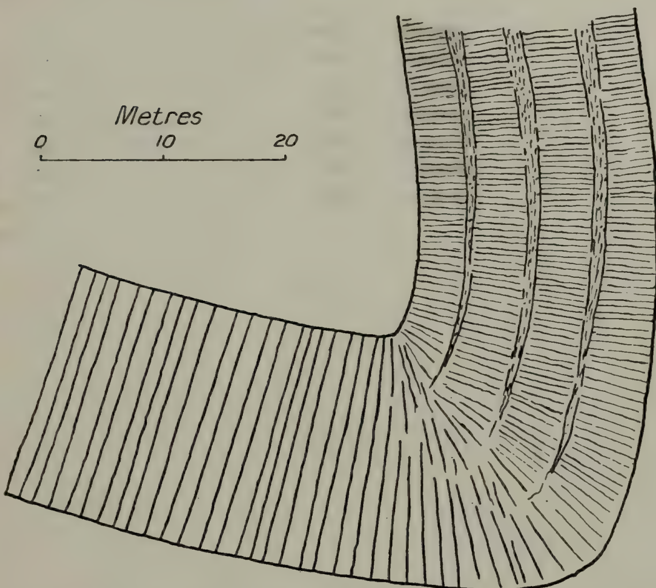


Diagram drawn to scale, showing development of columnar jointing in Tertiary basaltic flow near Ducks station. The gently dipping limb of the syncline is composed of regular columns of great size. The upturned limb is composed of four sets of regular but much smaller columns. The latter seem to have developed through orogenic stresses superposed on original cooling stresses.

great variation in age. Large areas had been undergoing erosion since the closing days of the Paleozoic; other areas, since the Triassic; others, since the late-Jurassic revolution; still others, since the Laramide revolution; while practically the whole Cordillera, except the part covered by Tertiary volcanics or local pockets of earlier Tertiary sediments, was being eroded during Eocene, Oligocene and Miocene times. We may well believe that, in places, the unceasing erosion of the whole (pre-Pliocene) Tertiary era, in spite of post-Oligocene deformation, had virtually produced local or widespread peneplains. Elsewhere moun-

tain torsos must have been the rule, except on the lava plains. In short, the early Pliocene Cordillera was a torso landscape, locally veneered with, and smoothed by, basaltic floods. It was this topographic composite, already close to sea level, which early Pliocene erosion somewhat further reduced toward a base level of fairly constant position.

Toward the close of the Pliocene all or nearly all of the Canadian Cordillera seems to have been elevated, to heights varying considerably, but reaching maxima of from 2,000 to 4,000 feet (610 to 1,220 m.). The streams so rejuvenated have had time to sink deep valleys in all three of the great Cordilleran Belts. This two-cycle topography is specially well illustrated in the Belt of Interior Plateaus, but it can be discerned in the Rocky Mountain trench, in the region around Revelstoke, and elsewhere along the railway section. The plateaus of the interior have been thus isolated from one another. In part, they represent dissected lava tables; in part, dissected local peneplains of pre-Miocene date; in part, dissected mountain torsos, reduced during the early Tertiary and the Mesozoic. There is no evidence that a *general* peneplain was developed over this part of the Cordillera at any time; nor is it proved that the upland facets of the Interior Plateaus were due to general peneplanation of that broad belt in late Miocene and early Pliocene time. A superficial study of the Interior Plateaus might lead to that conclusion; in reality, the upland relief has been conditioned by several pre-Miocene erosion cycles.

The Pleistocene glaciers gradually overwhelmed a mature to sub-mature topography. Their work represents a chapter of Cordilleran history already sketched; some of its details will be noted in annotations on the route to be followed by the excursionists. The recent changes in the late Glacial landscape are relatively slight and for the most part are too obvious to need formal statement in this place.

SPECIALLY NOTEWORTHY FEATURES.

In the midst of a multitude of problems and ascertained facts, certain aspects of the Cordilleran geology are worthy of special attention. Some of these are here listed for the convenience of the excursionists.

1. The great development of Cambrian sediments; their extraordinary richness in fossiliferous horizons and in new species and genera; the perfection with which some of this fauna has been preserved.

2. The unusually complete exposures and vast thickness of the Beltian system of rocks conformably underlying the Lower Cambrian.

3. Illustration of geosynclinal prisms of various ages.

4. The large area of pre-Beltian ("Archean") formations, including sediments, volcanics and orthogneisses.

5. Specially clear illustration of the efficiency of static metamorphism (Shuswap terrane and Beltian system).

6. The wide extent and great thickness of basic volcanics referred to the Triassic and to the mid-Tertiary.

7. The section through the Coast Range batholith, probably the most widely exposed intrusive mass of post-"Archean" date.

8. The evidences of a chemical origin for limestones and dolomites thousands of metres in thickness.

9. The opportunity of passing through the Rocky Mountain Geosynclinal into the terrane which furnished most of its clastic materials.

10. A view of the important unconformity at the base of the Rocky Mountain Geosynclinal.

11. The sections through the Rocky Mountain and Purcell trenches, two of the more remarkable depressions in the North American Cordillera.

12. The nature of the railway section as favourable to the discovery of field facts showing the relative shallowness of the earth-shell involved in orogenic folding.

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Indexes to North American Geology; Bulletins No. 127, 188, 189, 301, 372, 409, and 444 of the United States Geological Survey.

In these most of the important publications will be found under the names— G. M. Dawson, McConnell, McEvoy, Camsell, Walcott, Allan, and Dowling.

Especially to Dawson, the master in reconnaissance, geology owes the broad outlines already fixed for the Canadian Cordillera. A useful summary of its geology with leading references, is Dawson's 'Geological Record of the Rocky Mountain Region in Canada,' published in the Bulletin of the Geological Society of America, Vol. 12, 1901, pp. 57–92. His report on the Area of the Kamloops Map-sheet (427 pages) in Volume 7 of the Annual Reports of the Geological Survey of Canada is the most detailed work yet published on any large part of the railway section. In Volume 53 of the Smithsonian Miscellaneous Collections (1908), will be found C. D. Walcott's principal writings on the Cambrian and pre-Cambrian geology of the Rocky mountains in Canada.

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ROCKY MOUNTAINS (Bankhead to Golden).

BY

JOHN A. ALLAN.

STRATIGRAPHY.

COLUMNAR SECTION.

In the section across the Rocky mountains, between the Cascade trough near Banff to Golden and the Columbia valley, all the geological systems from the Pre-Cambrian to the Cretaceous inclusive, except the Triassic, are represented.

As shown in the tabulated section given below, the stratified rocks aggregate more than 52,628 feet (16,040 m.) in thickness. The thin-bedded strata, mostly shales, make up 23,730 feet (7,235 m.); the limestones, 20,528 feet (6,255 m.); the quartzites and sandstones, 8,370 feet (2,550 m.).

The relation between the Silurian and the Devonian systems is not shown in this area, because the Cambrian, Ordovician and Silurian formations are exposed mainly on the western slope of the Rocky mountains, while the remaining systems are exposed wholly on the eastern side of the Continental watershed.

TABLE OF FORMATIONS.

System.	Formation.	Approx. Thickness. Feet.	Approx. Thickness. Metres.	Lithology.
Recent and Pleistocene.	Fluviatile			Gravel, sand.
	Lacustrine			Gravel, sand, clay, silt and conglomerate.
	Glacial			Till.
	Erosion surface.			
Post-Cretaceous?	Igneous rock			Nephelite syenite, ijolite, urtite, jacupirangite, etc., with dykes.
Cretaceous	Upper Ribboned sandstone	550+	168+	Thin-bedded sandstone and shale with hard bands of sandstone.
	Kootenay Coal measures	2,800+	853+	Sandstone and shale with coal seams.
	Lower Ribboned sandstone	1,000+	305+	Thin-bedded brown sandstone and shale.
Jurassic	Fernie shale	1,500+	457+	Dark brown to black arenaceous shale; weathers into lens-like fragments.

Permian	Upper Banff shale	1,400+	427+	Dark brown arenaceous shale; weathering reddish and yellowish.
Mississippian	Rocky Mountain quartzite	800	244+	White to gray quartzite and arenaceous siliceous limestone.
	Upper Banff limestone	2,300+	701+	Thick-bedded dark gray limestones with numerous thin cherty layers underlain by thin-bedded limestone and shale; weathering gray.
Pennsylvanian	Lower Banff shale	1,200	366+	Black to dark gray shale, argillaceous and calcareous; weathering light brown.
	Lower Banff limestone	1,500+	457+	Thick-bedded gray limestones with numerous dolomitic segregations.
Devonian	Intermediate limestone	1,800+	548+	Thin-bedded limestones, with alternating more massive layers of gray dolomitic and siliceous limestone.
	Sawback limestone (age ?)	3,700+	1,127+	Thin-bedded limestone interbedded with less resistant layers and brownish and yellowish shale.
—*Contact relations not known.*—				
Silurian	Halysites beds	1,850+	563+	Dolomites and quartzites weathering light gray to white, with shale interbedded.

TABLE OF FORMATIONS—*Concluded.*

System.	Formation.	Approx. Thickness. Feet.	Approx. Thickness. Metres.	Lithology.
Ordovician	Graptolite shales	1,700+	518+	Black and brown fissile shales.
	Goodsir shale	6,040+	1,842+	Cherts, cherty and dolomitic limestones, siliceous and calcareous slates and shales.
Upper Cambrian	Ottertail limestone	1,725+	526+	Massive blue limestones with cherty and shaly bands.
	Chancellor	4,500+	1,372+	Thinly laminated gray argillaceous and calcareous meta-argillites and shales; weathering reddish, yellowish and fawn; underlain by highly sheared gray shales, slates, argillites and phyllites in Ottertail valley.
	Sherbrooke	1,375	419	Thin-bedded oolitic, arenaceous or dolomitic limestones.
	Paget	360+	110+	Massive bluish gray limestones, with oolitic bands of dolomitic limestone.
	Bosworth	1,855+	565+	Massive gray arenaceous and dolomitic limestone; weathering yellowish buff; interbedded with greenish siliceous shale; weathering, red, yellow and purple.

Middle Cambrian	Eldon	2,728	831	Massive-bedded arenaceous limestones forming cliffs and castellated crags.
	Stephen	640	196	Thin-bedded limestone, and shale; includes "Ogygopsis shale" in Mt. Stephen and "Burgess shale" in Mt. Field.
	Cathedral	1,595	486	Thin-bedded arenaceous and dolomitic limestones.
Lower Cambrian	Mt. Whyte	390	119	Siliceous shale, sandstone and thin-bedded limestone.
	St. Piran	2,705	824+	Ferruginous quartzitic sandstone.
	Lake Louise	105	32	Compact grayish siliceous shale.
	Fairview	600+	183	Ferruginous quartzitic sandstone. Local basal conglomerate and coarse-grained sandstone.
	Conformable in some places			
Pre-Cambrian	Hector	4,590+	1,399+	Gray, green and purple siliceous shale with conglomerate interbedded.
	Corral Creek	1,320	403	Quartzitic and coarse-grained sandstone with shale interbedded.
Base not exposed. Total thickness		52,628+	16,041+	

RESUME OF SECTION.

	Feet.	Metres.
Cretaceous	4,350+	1,326
Jurassic	1,500+	457
Permian	1,400+	427
Carboniferous	5,800+	1,768
Devonian	1,800+	548
Devonian (?)	3,700+	1,127
Silurian	1,850+	563
Ordovician	7,740+	2,360
Upper Cambrian	9,815+	2,992
Middle Cambrian	4,963	1,513
Lower Cambrian	3,800+	1,158
Pre-Cambrian	5,910+	1,802
Total	52,628+	16,041+

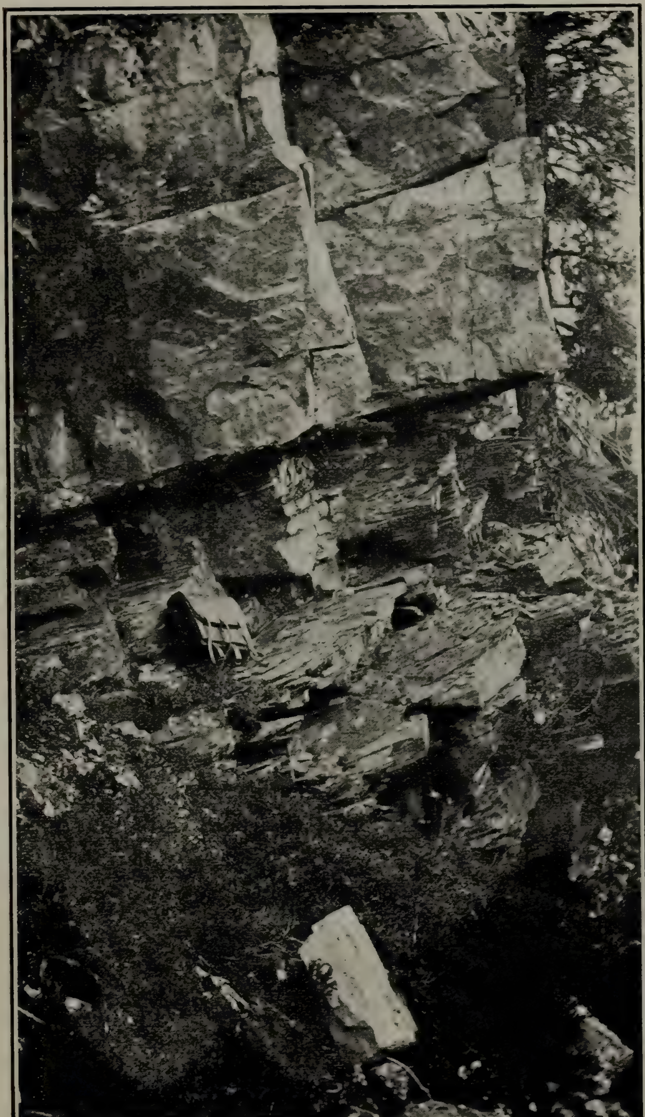
PRE-CAMBRIAN.

The Pre-Cambrian series is distributed along the floor and sides of Bow river valley from the base of Castle mountain, where it becomes faulted off against the younger Paleozoic rocks, to the head waters of the Bow river.

The contact between the Pre-Cambrian and the Cambrian is seldom exposed. It was examined at three localities. At one exposure in Bath Creek valley, near the summit of the Rocky mountains, the contact is a conformable one, while in two other localities in which the contact was exposed, there is a noticeable unconformity between the beds of the two systems. In one case the Pre-Cambrian shales were dipping 31 degrees S. 55° W., and the Lower Cambrian quartzites had a dip of 35 degrees S. 5° W.

The rocks in the Pre-Cambrian series, with the three lowest formations of the lower Cambrian, were formerly called the 'Bow River Group' by McConnell [**2**, p. 29].

Corral Creek Formation.—This formation includes the lowest beds exposed in the Rocky mountains, along this section. This series consists of gray sandstone underlain by a coarser quartzitic sandstone, with an arkose-like conglomerate at the base. The lowest beds are exposed in a railway cut two miles (3,249·2 m.) east of Laggan station. This rock is made up of small pebbles and grains of quartz, and angular crystals of white and pink feldspar. The cement is made up of finer material of



Contact of the Pre-Cambrian shales (Hector) and the Lower Cambrian quartzites. Exposed in Bath creek west of Laggan.

the same composition. The nature of this rock suggests shallow-water or near-shore conditions of origin.

Hector Formation. The beds in this formation consist of gray, purplish, and greenish shale interbedded with bands of conglomerate 15 m. to 75 m. thick. The best exposure is in the Bow range east of Storm mountain, where the formation has a minimum thickness of 4,590 feet (1,399 m.). It thins out towards the northwest; in Mt. Temple, Walcott measured over 2,150 feet (655 m.), and at Fort mountain towards the head of Corral creek he obtained a section 1,302 feet (397 m.) thick.

From one layer of shale (50 cm. thick), outcropping on the eastern base of Storm mountain and about 16 metres from the top of the series the writer collected fossil remains of a brachiopod-like shell about one-eighth of an inch in diameter. This is the only locality in which fossil remains have yet been found.

CAMBRIAN.

The Cambrian series is complete in this section with both lower and upper contacts exposed. There is a total thickness of over 18,578 feet (5,663 m.). This represents one of the thickest Cambrian sections yet measured in the world. It essentially consists of 3,800 feet (1,159 m.) of siliceous beds, principally quartzitic sandstone; 10,275 feet (3,132 m.) of calcareous and dolomitic limestone, and 4,500 feet (1,371 m.) of shale, much of which is calcareous. The various divisions of the Cambrian series have been made on paleontological and lithological evidence. The formations in the Lower and Middle Cambrian and the first three in the Upper Cambrian were named and measured by Walcott, [**7,** p. 204]; the remaining two formations were named and measured by the writer.

LOWER CAMBRIAN.

Fairview Formation.—The Fairview formation consists of brown and white quartzitic sandstone. Locally there is a basal conglomerate on the Pre-Cambrian shales; it consists of rounded pebbles of white quartz, up to 7 cm. in diameter, in a cement of quartz, feldspar and mica. The basal rock is more frequently a coarse sandstone with rounded and angular grains of quartz and feldspar,

5 to 15 mm. in diameter. Some of the quartz grains have a glassy, almost opalescent colour.

Lake Louise Formation.—As the name indicates, these beds are best exposed at Lake Louise. The formation has a total thickness of 105 feet (32 m.) and consists of a ferruginous siliceous shale. It weathers more readily than the beds below or above, so that the slopes are more gradual.

Mt. Temple, showing a complete Lower and Middle Cambrian section capped by Upper Cambrian, and underlain by Pre-Cambrian shales (covered by talus).

St. Piran Formation.—This formation consists of massive-bedded, ferruginous, quartzitic sandstone, with a total measured thickness of 2,705 feet (824 m.). These beds form steep escarpments wherever they are exposed. On the west side of Mt. Victoria the cliffs composed of these beds are over 2,500 feet high. The brown color of the rock is due to smoky quartz and small particles of mica in the cement.

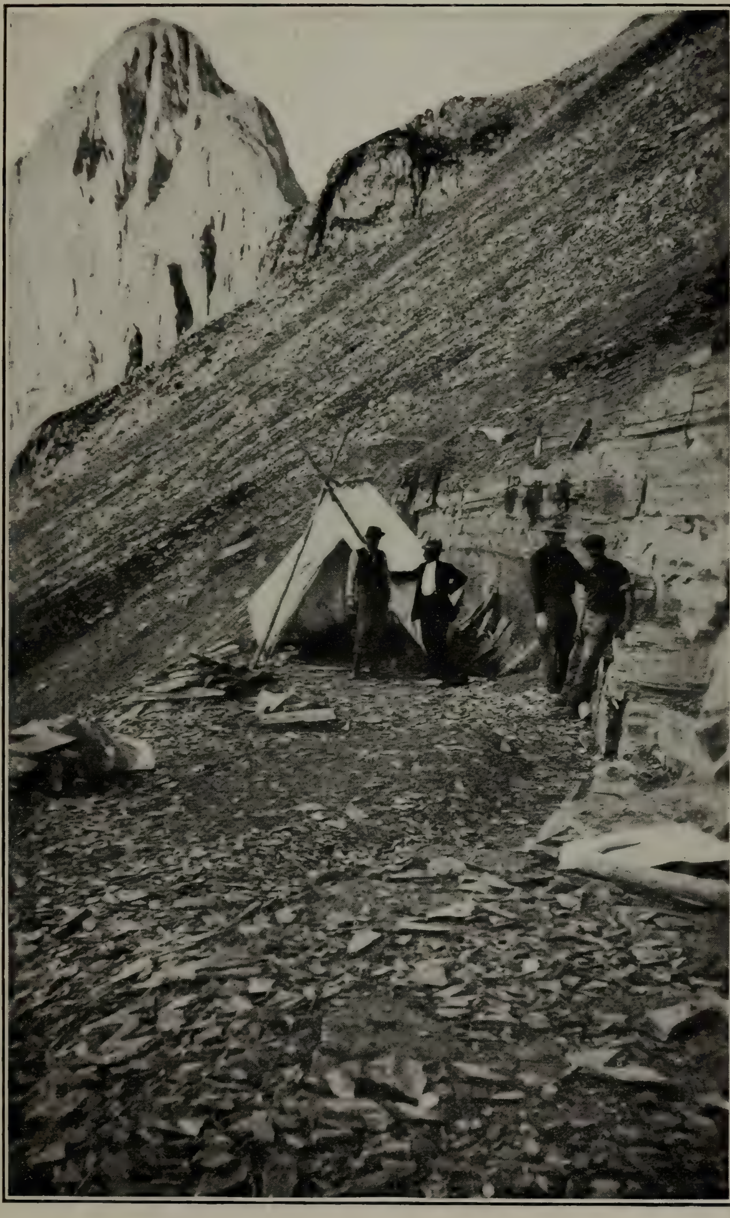
Mt. Whyte Formation.—In sharp contrast with the underlying massive quartzites, there is a thin series of siliceous and calcareous shales grouped as the Mt. Whyte formation. These shales are less resistant than the quartzite and form gradual slopes. Some of the layers contain numerous annelid borings and trails.

Cathedral Formation.—This formation consists of massive and thin bedded dolomitic limestone, which on the weathered surface becomes buff and gray. The more massive beds are arenaceous in their composition. It is on this formation that the Monarch mine in Mt. Stephen is situated, and other small mineral prospects in the Kicking Horse valley.

Castle Mountain, showing Cathedral limestone in the lower cliffs; Stephen formation in the talus covered slope; and the Eldon formation in the upper cliffs. (All Middle Cambrian).

Some of the limestone has become metamorphosed into marble. One of the best exposures of this rock is in Cathedral mountain, four miles (6·4 km.) east of Field.

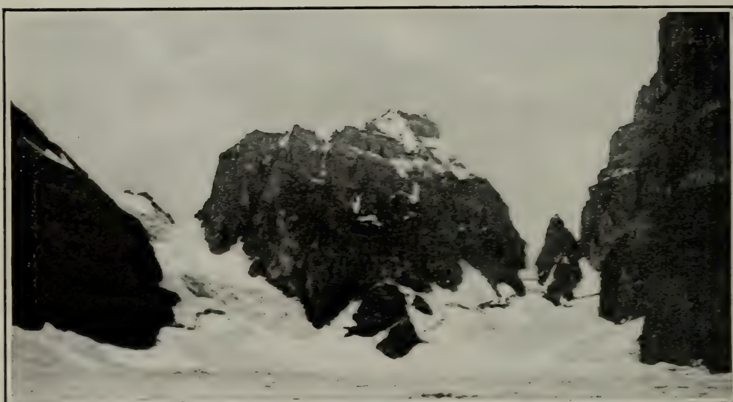
Stephen Formation.—Although this formation is only 640 feet (196 m.) thick, yet it is quite important for the number and variety of fossils which it contains. It consists of shaly limestone and calcareous shale. These beds include the 'Ogygopsis shale' in Mt. Stephen, and the 'Burgess shale' in Mt. Field, on the opposite side of the valley. The former includes the widely known trilobite-bearing 'fossil bed,' while the latter includes the new 'fossil bed,' discovered by Walcott in 1910. From this bed he has obtained an extensive variety of Middle Cambrian organisms. Coelenterata, Annulata, Echinoder-



Fossil bed in "Burgess shale" on Mt. Field, showing character of the shale, method of quarrying for fossils, and temporary camp of C. D. Walcott.

mata and certain Arthropoda are abundantly represented [**10**].

Eldon Formation.—This formation has a thickness of 2,728 feet (831 m.) where it was measured in Castle mountain. It consists essentially of massive-bedded, arenaceous limestones, which form steep castellated crags on the erosion surface, thus making the formation readily recognizable wherever exposed. It is this formation which forms the steep escarpment about the upper part of Castle mountain.



The Mitre and Death Trap (pass) to the right. The cliffs on the right are of Middle Cambrian limestone in Mt. Lefroy. A typical bergschrund is shown around this portion of the Lefroy glacier.

UPPER CAMBRIAN.

Bosworth Formation.—This formation is exposed in the mountain of the same name on the Continental Divide. It consists largely of thin-bedded limestone with a few more thick-bedded layers, interbedded with siliceous and arenaceous shale. One band of shale makes a good horizon-marker because it weathers greenish, yellowish, deep red, and purplish.

Paget Formation.—A band of grayish oölitic limestone, typically exposed in Paget peak, on the west slope of Mt. Bosworth, has been placed in this formation. These beds can not be readily distinguished from the underlying limestone.

Sherbrooke Formation.—Arenaceous limestone at the base of this formation is overlain by thin-bedded limestone, including some oölitic and shaly layers. This formation includes the highest beds exposed in the Bow Range in the vicinity of Hector Pass.

The remaining Cambrian formations, the Ordovician, and the Silurian are all exposed in the western portion of the section between the Bow range and Columbia valley.

Chancellor Formation.—This formation consists essentially of shales which weather reddish, yellowish, fawn or gray. The uppermost 2,500 feet (762 m.) are gray met-argillites, well cleaved along the bedding planes, and weathering reddish and yellowish. These shales become much more highly cleaved towards the base of the formation, so that the lowermost, 2,000 feet (610 m.) thick, consist chiefly of phyllites and slates, with argillites and a few interbedded layers of shaly limestone. The ferruginous content in all the beds is high, so that the weathered surface is usually reddish or yellowish. This series floors Ottertail valley, underlies the Ottertail range, and makes up a large part of the Van Horne range.

Ottertail Limestone.—This formation consists almost entirely of blue limestone, massive towards the top and rather thin-bedded towards the base. It has a thickness of over 1,725 feet (526 m.) in the Ottertail range, where it is well exposed in an almost perpendicular escarpment along the east side of the range. The cliff-forming character of this formation marks it off very sharply from the shale formations below and above.

This limestone represents the highest series in the Cambrian in this portion of the Rocky mountains.

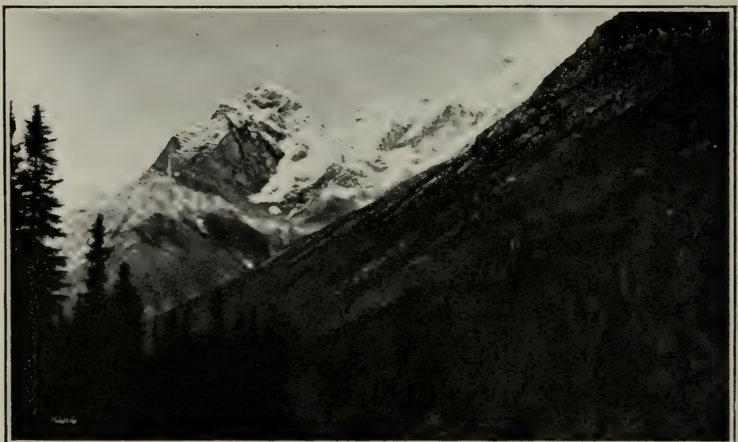
ORDOVICIAN.

Goodsir Shales.—This formation is best exposed in Mt. Goodsir, where it has a measured and estimated thickness of over 6,040 feet (1,841 m.). It lies conformably on the Ottertail limestone and consists at the base of almost 3,000 feet (914 m.) of alternating hard and soft bands of argillaceous, calcareous, and siliceous shale, which weather light yellowish, gray and buff.

The upper part of the formation consists of banded cherts, cherty limestones and dolomites, thin-bedded and

very dense, so that they weather into compact angular fragments. The beds in this series become very highly sheared in the Beaverfoot valley and the range to the west.

On both paleontologic and lithologic evidence the boundary between the Cambrian and the Ordovician in this district is placed at the top of the Ottertail limestone and at the base of the Goodsir shale.



Cambrian–Ordovician contact in Mt. Goodsir. The gray rock is the Ottertail lime-limestone, overlain by the dark-colored Goodsir shales.

Fossils were found near the base of the Goodsir formation at several localities, and have been determined by Walcott. The following new species have been identified from this series.:—

Obolus mollisonensis.
Lingulella? allani.
Lingulella moosensis.
Ceratopyge canadensis.

The presence of the Ceratopyge fauna places this formation at the base of the Ordovician, corresponding to the horizon of the Ceratopyge shale in Sweden.

The sedimentary series from Mt. Whyte to Goodsir, inclusive, were included by McConnell in his Castle Mountain group.

Graptolite Shales.—These beds have been so named by McConnell on account of the richness of certain layers in graptolites. The presence of this fauna determines the age of the formation as Ordovician.

The Graptolite shales consist of black, carbonaceous, and brown, fissile shale at the top, underlain by gray shales which grade into the underlying Goodsir formation.

The thickness of the formation varies and the lower contact is ill-defined, but a thickness of at least 1,700 feet (518 m.) is represented. These shales occur as two infolded bands in the Beaverfoot range.

SILURIAN.

Halysites Beds.—The Halysites beds consist chiefly of dolomitic limestone and white quartzite. This formation lies conformably upon the Graptolite beds. The character of the rock sharply distinguishes it from the older strata. The formation is terminated above by a fault contact or by an erosion surface. A measured section gave 1,850 feet (563 m.). The white quartzite is over 900 feet thick (274 m.). It is infolded with the graptolite beds in the Beaverfoot range. Some of the beds of dolomitic limestone are highly fossiliferous; corals are most abundant, but crinoids, brachiopods, and gastropods are also present.

This is the youngest formation exposed to the west of the Continental Divide, along this section of the Rocky mountains.

DEVONIAN.

Intermediate Limestone.—This formation consists of thin-bedded limestones, alternating with harder layers of gray dolomitic and siliceous limestone, which on the weathered surface becomes banded. In the Sawback, Vermilion Lake and Cascade ranges it is exposed, being repeated by reversed faulting.

The thermal sulphur springs at Banff occur in the Intermediate limestone. The rock is high in sulphur, derived by the decomposition of pyrite which the limestone contains; a strong odor of sulphide of hydrogen is given off when the rock is struck with a hammer.

Some of the beds are highly fossiliferous. Zaphrentis and brachiopods are the most abundant forms present.

The upper limit of this formation is not clearly defined as it is transitional into the Lower Banff shale.

Sawback Formation.—Underlying and conformable with the Intermediate limestone is a series of massive and thin-bedded, dolomitic limestone and shale, which McConnell has placed in the Cambrian. These form a wedge-shaped band in the Sawback range and lie between Mt. Hole-in-the-wall and Mt. Edith, with a broader exposure along the north side of the Bow valley. It has been possible to measure and estimate a thickness of about 3,700 feet (1,128 m.) but the actual thickness is believed to be much greater. Fossils have not yet been found in this series. Since they differ lithologically from the Cambrian beds in Castle mountain, which are largely Middle Cambrian, and from the Cambrian in the Bow range and to the west of this range, it is proposed to call this series Sawback limestone. The age of the formation is still in doubt but it is older than the Intermediate limestone, which is definitely known to be Devonian in age. These beds are lithologically closely related to some of the Silurian beds in the Beaverfoot range to the west.

MISSISSIPPIAN.

Lower Banff Limestone.*—This formation grades into the Devonian limestone below, so that it is not possible always to draw a sharp dividing line between these two formations. It is quite clearly defined on its upper contact, as the overlying formation is a shale. The beds consist of massive-bedded, gray limestone which forms steep escarpments wherever exposed on the slopes of a mountain.

This limestone forms the eastern cliffs of Cascade mountain, and Mt. Rundle; and the steeper eastern slopes of Sulphur mountain. Some beds are fossiliferous, and the formation is characterized by numerous fossil-like dolomitic segregations. Many of these resemble certain types of bryozoan remains.

Lower Banff Shale.—There are about 1,200 feet (366 m.) of shale included in this formation. These shales are black to dark gray in colour and weather brown.

*Since Dr. Allan sent his MS. to press, Dr. H. W. Shimer has found that the fossils recently collected in this limestone show it to be largely if not wholly of Devonian age.

They are usually calcareous in composition, but certain layers are argillaceous and arenaceous. The lower contact of this series is sharply defined but at the top of the series the beds change to a shaly limestone difficult to distinguish from the overlying limestone. The shales weather out more easily than the limestone, so that a depression is always formed where these shales cut across a ridge. A leading fossil is *Spirifer centronatus*.

PENNSYLVANIAN.

Upper Banff Limestone.—There are over 2,300 feet (701 m.) of beds included in this formation, which is well exposed in Sawback and Cascade ranges. The series is shaly at the bottom, but more massive towards the top. Cherty lenses and cherty shale interbedded with the lower shaly limestone help to distinguish this formation from the shales below. Fossils e.g., *Spirifer rockymontanus*, are quite abundant throughout the lower beds in this series.

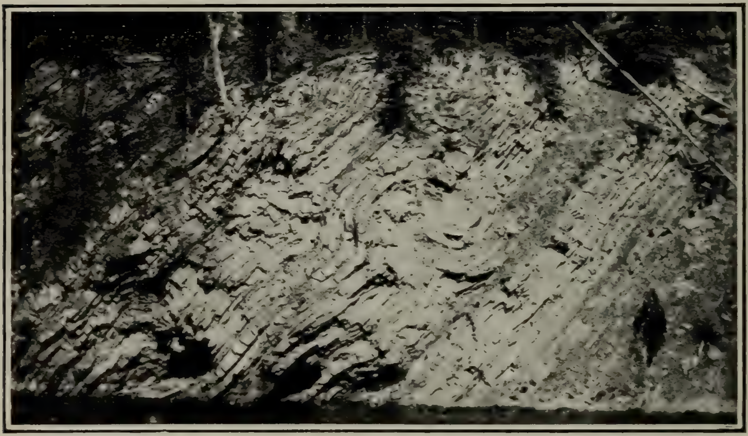
Rocky Mountain Quartzite.—This quartzite lies directly on the Upper Banff limestone. It represents a very sudden shallowing of the water, which, however, was not rendered muddy. The section in the Sawback range gave 800 feet (244 m.) as a maximum thickness. There is a rapid thickening of this formation to the east so that at Lake Minnewanka, 12 miles (19 km.) to the east, there are 1,600 feet of quartzite exposed. Certain portions of the formation are quite fossiliferous. These fossils e.g., *Euphemus carbonarius*, can most readily be found on the weathered surface.

This is the uppermost formation in the Carboniferous. The lower two formations have been grouped as Mississippian in age, while the upper two correspond to the Pennsylvanian. [**9**, p. 147].

PERMIAN.

Upper Banff Shale.—This formation lies conformably upon the quartzite and consists of a series of brown, calcareous and arenaceous, often sun-cracked shales interbedded with thin layers of sandstone. The shales weather out more easily than the underlying formations, forming valleys such as those between the Cascade, Vermilion Lake, and Sawback ranges. More than 1,400 feet

(427 m.) of strata are represented in this section, but it is difficult to get an accurate measurement on account of the foldings and contortions within the beds. A leading fossil is *Schizodus*.



A typical view of the Upper Banff shale, exposed in Spray valley at Banff.

JURASSIC.

Fernie Shale.—No sharp line can be drawn between the Upper Banff and Fernie shales, except where fossils are found. The Fernie formation consists of black and dark brown, siliceous, very thinly laminated shales which break up into small fragments on the weathered surface. West of Banff it has a limited distribution, lying on the Upper Banff shale. East of Banff and on the north side of the Cascade trough, it forms a band about 1,500 feet (457 m.) thick. The Fernie shale was examined near Exshaw 6 miles (9·6 km.) east of the Gap. A certain layer was found to contain clay concretions of which the largest was 35 cm. in diameter. Another layer, 15 cm. thick, contained numerous bone fragments. One large reptile-like jaw-bone is 22 cm. long. There are many smaller fragments of bone and teeth. Ammonites are very common in the Fernie shale.

CRETACEOUS.

Lower Ribboned Sandstone.—The Cretaceous beds are exposed along the eastern base of Cascade mountain. The Lower Ribboned sandstone consists of alternating bands of brown-weathering sandstone and shale. This formation follows the bottom of the Cascade trough and is exposed on the road between Bankhead and the west end of Lake Minnewanka. The beds are here about 1,000 feet (305 m.) thick.

Kootenay Coal Measures.—This formation consists of 2,800+feet (853+m.) of sandstone and shale enclosing several workable seams of coal. There are fourteen seams exposed at Bankhead, where the coal is being mined, and nearly twice as many have been found at Canmore down the Cascade trough. The coal is bituminous and anthracitic. Several of these seams are being mined at Canmore. The coal measures are well defined between two massive sandstone bands which form roof and floor.

Upper Ribboned Sandstone.—This formation consists of thin-bedded sandstones and shales. It is exposed at the eastern base of Cascade mountain. The beds are wedged between the coal measures below, and a thrust plane above. Some of the uppermost Cretaceous beds were planed away when the older beds were thrust over them. There are about 550 feet (168 m.) of beds exposed in Cascade mountain, but this formation becomes thicker where it is exposed to the northwest and southeast of this section.

POST-CRETACEOUS.

Igneous Complex.—The only igneous rock in the Rocky Mountain section is represented by the Ice River intrusive complex, which has the form of an asymmetrical laccolith with a stock-like conduit. It has an area of about 12 square miles (31 sq. km.).

The rocks of the complex are all alkaline in composition, ranging from nephelite syenite and sodalite syenite through urtites and ijolites, to a jacupirangite or alkaline pyroxenite. These diverse types represent a complete petrographic series with intermediate facies.

The age of the intrusion is believed to be post-Cretaceous as determined by structural and correlation evidence.

PLEISTOCENE AND RECENT.

The unconsolidated material is represented by three types of deposits as shown in the section. The fluviatile and lacustrine deposits appear in terraces about the sides of the larger valleys, while the former also floors the broad flood plains of the main streams, such as the Bow, the Kicking Horse, the Beaverfoot and the Yoho.

Glacial till veneers the more gradual slopes of the various ranges, to an elevation at least 9,000 feet (2,743 m.) above sea-level.

ANNOTATED GUIDE.

(Bankhead to Golden).

BY

JOHN A. ALLAN.

Miles and Kilometres.

79·5 m. 127·2 km. from Calgary.

Bankhead—Alt. 4,510 ft. (1,375 m.). This station lies to the western edge of the Cascade coal basin described by Dowling [**1**].

About one mile east of this siding the railway leaves the bottom of Cascade valley and, turning at 90 degrees to the southwest, passes between Cascade mountain on the north, and Tunnel mountain on the south. This was at one time the course of Bow river, but the channel was obstructed by the gravels brought down by Forty Mile creek, as well as by the moraine left by the continental ice sheet, so that now the Bow passes through this range between Tunnel mountain and Mt. Rundle.

The structure of the beds in Cascade mountain is well shown in the cliff to the right of the railway. The beds are steeply dipping to the west and terminate in a precipitous cliff on the east. The cliffs at the base are Intermediate limestone (Devonian), overlain by Lower Banff limestone (Lower Carboniferous). The Lower Banff shale above (also Lower Carboniferous) weathers into talus-covered slopes. The mountain is capped by Upper Banff limestone and

Miles and Kilometres.

Rocky Mountain quartzite (Upper Carboniferous). An overthrust fault-line scarp defines the steep eastern face of this mountain; the Devonian limestones are thrust over the Cretaceous coal measures. This fault-line defines the southwest side of Cascade valley. It is exposed in the base of the Three Sisters, and extends to the southeast along the eastern face of the Livingstone range at the Crowsnest Pass, and into Montana, where it is known as the "Lewis thrust." It has not been possible to measure the actual amount of displacement, but there is a vertical throw of about three miles (4·8 km.) in Cascade mountain. McConnell [**2**] has estimated that the front ranges of the Rocky mountains have been thrust about seven miles (11·2 km.) over the plains to the east, but it it not possible to measure the horizontal displacement in the Cascade Mountain thrust fault.

A spur runs from Bankhead station to the Bankhead coal mines, about two miles (3·2 km.) to the northeast. These mines are owned and operated by the Canadian Pacific Railway Company. They are situated in the Kootenay coal measures which are Lower Cretaceous in age. The coal is bituminous and semi-anthracite. The plant is well equipped with a large breaker and a briquetting mill.

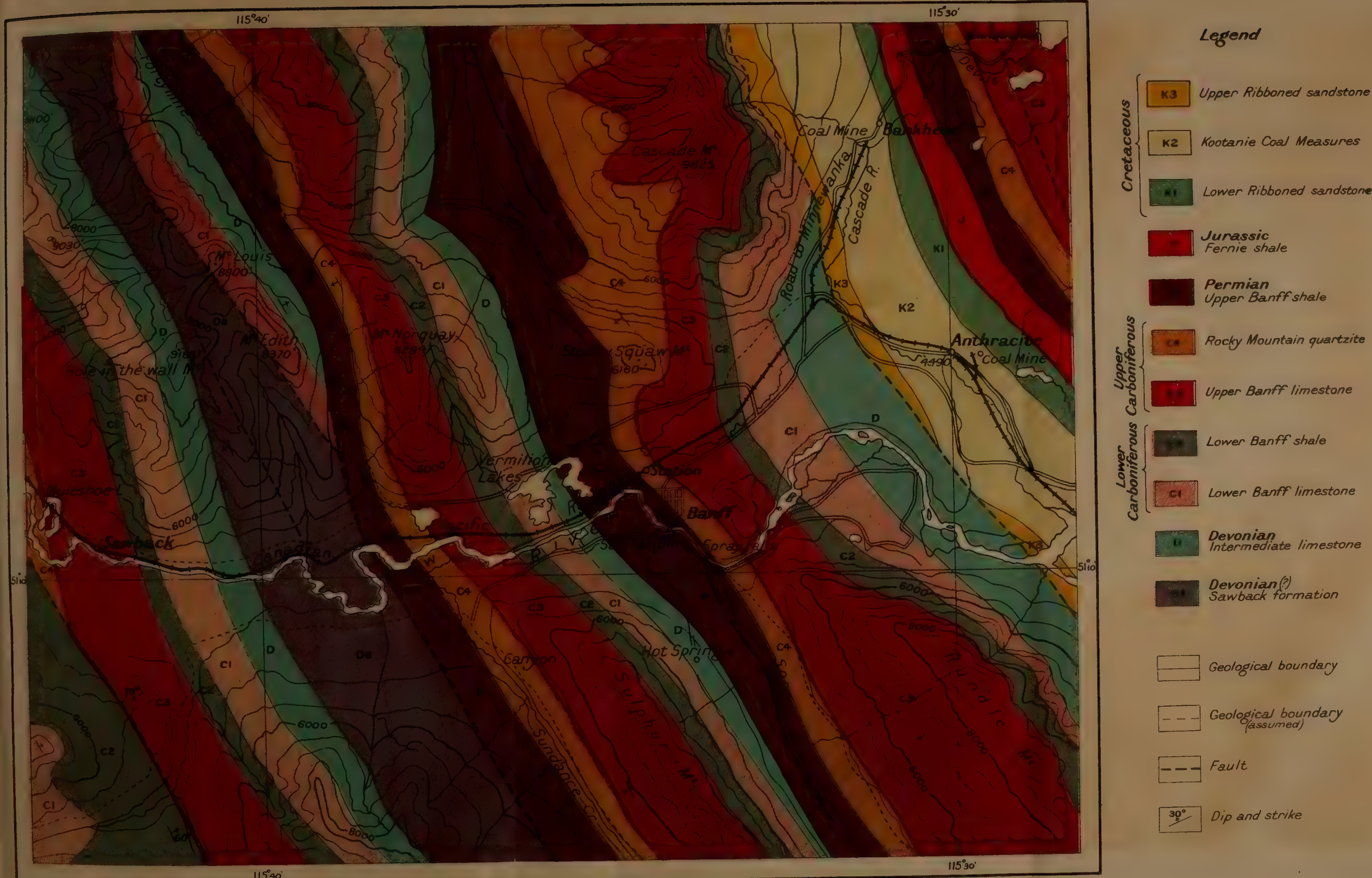
Between the coal mines and Lake Minnewanka a section along Cascade river exposes Cretaceous, Jurassic, Permian and Upper Carboniferous beds. This section has been studied in detail by H. W. Shimer [**3**]. Fossils are abundant, expecially in the Rocky Mountain quartzite. For a portion of this distance the driveway follows along the top of a morainal ridge. In Pre-Pleistocene time Cascade river drained out by Lake Minnewanka and Devil's Gap to the plains, but in recent time it has cut through the thick morainal detritus and has joined Bow river four miles (6·4 km.) east of Bankhead station.

Miles and Kilometres.

82 m. 131·2 km. **Banff**—Alt. 4,521 ft. (1379 m). This is the gateway to the Rocky Mountain National Park. This reservation covers 5,732 square miles (14,330 sq. km.), and contains many features of interest. Some of those to be visited are the hot sulphur springs, sulphur caves, Sulphur Mountain observation station, and the buffalo paddock. Looking west from the station are seen the snow-capped peaks of the Bourgeau range, ten miles (16·1 km). distant. The town lies west of Tunnel mountain. On the north side of the valley are Cascade mountain and a subsidiary ridge, Stoney Squaw mountain, in which is shown the eroded end of an asymmetrical anticlinal fold.

A few yards to the west of the station Bow river turns sharply to the southeast, and after passing the town and cascading over a very picturesque fall, it is joined by the Spray. At this point, close to the Banff Springs hotel, the river is diverted at right angles to the east and passes between Tunnel and Rundle mountains. The valley of the Spray river is floored with soft Permian and Jurassic shales. The accompanying figure shows a typical view of the Upper Banff shale (Permian), exposed in Spray valley. This valley is defined by a fault so that the beds in Sulphur mountain repeat those exposed in Cascade and Rundle mountains. The Fernie shales (Jurassic) are characterized in certain layers by the abundance of ammonites.

On the east slope of Sulphur mountain are situated the hot sulphur springs. The upper one is 500 feet (152·5 m.) above the town. The water comes from the orifice at a temperature of 114·2 degrees Fahr. (45·6° C). This sulphuretted water has a marked medicinal effect, and many people visit Banff on this account. A second or middle hot spring is 200 feet (60 m.) lower down the slope, and a mile and a half (2·4 km.) farther to the



Geological Survey, Canada

Banff

Miles

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Kilometres

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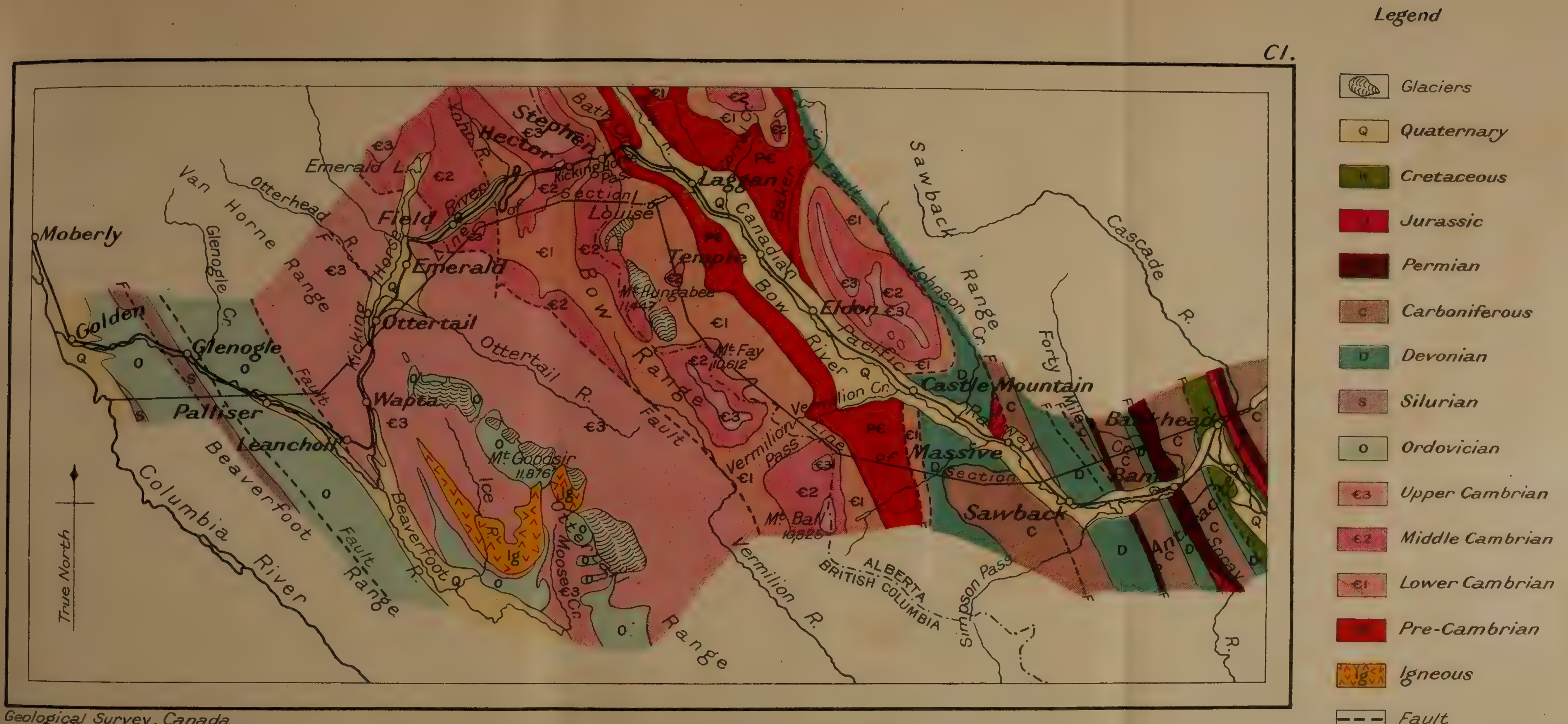
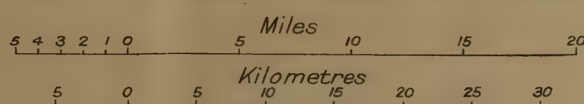


Route map between **Banff** and **Golden**



Miles and Kilometres.

northwest. The spring is not so strong as the upper one, and the temperature of the water is about 90° F. (32·2°C). A third or lower spring is situated farther to the northwest and about 50 feet (15 m.) above Bow river. The water is at a lower temperature than either of the upper two. Locally this spring is spoken of as the "Cave and Basin", because the spring rises into a cavern about 20 feet (6 m.) in diameter. By means of an underground channel it escapes to a natural basin formed in the calcareous tufa deposited. A second cave has been recently discovered a few yards farther up the slope. The interiors of these caves are coated with sulphur crystals. The Dominion Park Commission is erecting a substantial bath house at this spring for the accomodation of the public. Other warm springs are located in the bottom of Bow valley, about the Vermilion lakes. All of these springs are located in the Intermediate limestone (Devonian).

From the summit of Sulphur mountain can be seen the general monoclinal structure of this portion of the Rocky mountains. The successive ranges from the Cascade valley westwards represent westerly dipping fault blocks, which have become tilted along the east side. On the north side of Bow valley the Cascade, Vermilion Lake and Sawback ranges form distinct units, the same beds being repeated in each of these ranges.

83 m. Leaving Banff station the railway follows
132·8 km. along the broad swampy valley of the Bow, on the right of which is a series of three small lakes, called Vermilion lakes. The range to the right is the Vermilion Lake range, in which are exposed the westerly dipping Devonian, Carboniferous, Permian and Jurassic beds.

85 m. This creek follows a fault line which divides
136 km. the Vermilion Lake range from the Sawback range. This depression leads to Edith pass, beyond which can be seen Mt. Edith, which is made up of vertically dipping Lower Banff

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limestone. The steeply dipping beds on the west of this creek belong to the Sawback formation. This formation lies conformably under the Devonian Intermediate limestone, but the exact age is still doubtful, as no fossils have yet been found in it. Lithologically, a part of this series resembles the rocks of Silurian age in the Beaverfoot range to the west. To the south of the railway is the valley of Healy creek which extends to Simpson pass, and is the course followed en route to Mt. Assiniboine, the Matterhorn of the Canadian Rocky mountains. Bow river has here a meandering course, some of the lobes having been cut through, to form oxbow lakes.

88 m.
140·8 km. **Sawback.**—Alt. 4537 ft. (1,384 m.). West of Banff the railway crosses the strike of the formations in the Vermilion Lake and Sawback ranges, but at this point the valley of the Bow turns sharply to the northwest and follows along the strike of the formations as far as Laggan. The Carboniferous limestones dip at about 65° to the southwest, so that smooth cliffs formed along the bedding-planes are characteristic of the Sawback range. Mt. Hole-in-the-Wall, to the north of the station, is so called because it contains in its side a cavernous opening. This cave at its outer end is 50 feet (15 m.) in diameter, but becomes smaller behind as the floor rises. It is about 150 feet (46 m.) long and is situated, 1,500 feet (458 m.) above the railway, in the Lower Banff limestone. The position of the Lower and Upper Banff shales is always readily recognized by a depression on the surface.

93 m.
148·8 km. **Massive**—Alt. 4,600 ft. (1,402 m.). On the south side of Bow valley, Pilot mountain towers 5,000 feet (1,513 m.) above the railway. The base consists of Devonian limestone, and the peak is capped by Upper Carboniferous. From the Intermediate limestone in Fossil mountain, 10 miles northeast of Laggan, the following Upper Devonian fauna have been determined:—*Spirifer whitneyi* Hall; *Productella*

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hallana Walcott; *Stropheodonta demissa* (Conrad), *Schizophoria striatula* (Schlotheim), *Chenungensis var. arctostriatus* (Hall), *Phillipsastraea verrilli* Meek, *Syringopora cf. perelegans* Billings, and other Devonian species.

A few yards beyond the west end of the siding, the railway cuts through a down-faulted block of dark brown Fernie shales containing ammonites, which indicate that they are Jurassic in age.

96·2 m.
153·9 km. The upper part of Johnson creek separates Sawback range from Castle Mountain range. It follows in a fault valley. Four miles from its mouth the stream has been diverted to the south by the down-faulted block of Jurassic shales referred to above. From this point there is an excellent view of Castle mountain with its perpendicular cliffs and broad amphitheatre behind.

99 m.
158·4 km. **Castle**—Alt. 4,660 ft. (1, 420 m.), is situated at the base of Castle mountain. West of the station the railway follows along the base of this mountain for over 10 miles (16·1 km.). The eastern end of the mountain is terminated by a large pinnacle which, from the railway, resembles the ruins of a massive castle; hence the name. The accompanying illustration shows the character of the rock in Castle mountain. The upper slopes are Cambrian. It is capped by the thin-bedded red-weathering limestones and shales of the Bosworth formation (Upper Cambrian). The perpendicular cliffs at the top represent the Eldon formation. This is the type locality and this formation has a measured thickness of 2,728 feet (832 m.). The Stephen formation is about 600 feet (183 m.) thick, and forms a very flat talus-covered slope, while the Cathedral formation below is about 1,500 feet (458 m.) thick and forms a precipitous slope. These three formations are Middle Cambrian in age. The Lower Cambrian beds are largely quartzitic and form brush-covered, irregular slopes.

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Castle was an active town with about 1,500 people in 1884-86, but is now deserted. The "boom" was caused by the discovery of copper prospects in Copper mountain directly south of the station on the opposite side of the valley. Mining proved a failure. And there is now only one of the old timers, James Smith, living here.

There are numerous foundations on this flat, but most of the buildings have been burned or torn down.

100 m. 160 km. The Dominion government is building an automobile road across the Rocky mountains from Calgary to Golden. The road here crosses the railway and Bow river; it follows up Vermilion creek to the south, over the Vermilion Pass, and down Vermilion river to the Kootenay, thence into the Columbia valley and down to Golden. The road is nearly completed up to the pass, which, with an elevation of 5,264 feet (1,605 m.), is the lowest pass in this part of the Rocky mountains. To the east of Vermilion Pass is seen the craggy cliffs of Storm mountain (altitude 10,309 feet) in the Middle and Lower Cambrian formations. The lower rounded ridges to the east are formed of Pre-Cambrian shales. The contact, apparently slightly unconformable, is exposed at the eastern base of Storm mountain.

105·5 m. 170·4 km. **Eldon**—Alt. 4,817 ft. (1, 468 m.). The broadly rounded Bow valley is underlain by the softer Pre-Cambrian shales included in the Hector and Corral formations. The Pre-Cambrian beds floor the Bow valley and the lower slopes up to Kicking Horse pass, and to the head waters of Bow river. This series has been called Pre-Cambrian by Walcott [**4**], because the beds are largely unfossiliferous and underlie the Olenellus zone of the Lower Cambrian. These beds represent a portion of the Bow river group, defined by McConnell [**5**]. A few brachiopod-like fossils were found by the writer in a layer of Hector shale at the base of Storm mountain.

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112 m. 179·2 km. Between this point and Laggan one has the best view of the valley of Ten Peaks, also Paradise valley and the majestic peaks of the Bow range. The peaks which stand out in prominence are a few of the Ten Peaks, including Mt. Fay and Mt. Deltaform (11,225 ft.—3,421 m.); also Mt. Temple (11,626 ft.—3, 544 m.), the highest peak in the range visible from the railway. On approaching Laggan, Fairview, Aberdeen, Whyte, and Victoria become visible.

113·9 m. 182·2 km. The first and lowest exposure of Pre-Cambrian occurs to the right of the railway. It is a coarse pebbly sandstone containing pink felspar.

115 m. 184 km. **Laggan**—Alt. 5,037 ft. (1,535 m.). From this point, type localities for Cambrian and Pre-Cambrian formations will be visited. A driveway and a railway lead up to Lake Louise and the Chalet. This lake is situated over 600 feet (183 m.) above Bow river, at the front of a large cirque which is occupied at the south end by Victoria and Lefroy glaciers. The lake is surrounded by Lower Cambrian quartzites of which the St. Piran formation stands out in prominence and forms precipitous cliffs. The contact between the Lower Cambrian quartzites and the Middle Cambrian limestones is well shown in the lofty mountains about this valley. The illustration on page 178 shows the Mitre with Mt. Lefroy on the right, Mt. Aberdeen on the left, and a portion of the Lefroy glacier with a well defined bergschrund. The cliffs are Lower Cambrian, and the Mitre is capped with the Cathedral limestone of the Middle Cambrian. The pass to the right is called the Death Trap on account of its dangerous position.

A visit will be made to Valley of the Ten Peaks, and the mouth of Paradise valley will be passed on the way. Both are typically hanging glacial valleys with glaciers at their upper termini. In the former the valley is

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surrounded by ten gigantic peaks each of which shows the Lower and Middle Cambrian formations. Moraine lake lies in this basin between a large moraine and the Wenchemna glacier. Mt. Temple (11,626 feet), (3,543·6 m.), the highest in this part of the Rocky mountains, stands between these two valleys. The talus slope shown in the illustration on page 175 shows the position of the contact between the Pre-Cambrian and the Cambrian. The Middle Cambrian begins at the change in slope in the cliffs on the left, and the peak is capped by Upper Cambrian thin-bedded limestones of the Bosworth formation.

Leaving Laggan station, a good exposure of Pre-Cambrian slates and shales wiil be visited within 200 yards (183 m.) of the west end of the railway yards. The illustration on page 173 shows the conformable contact between the Pre-Cambrian shales of the Hector formation and the Lower Cambrian quartzites. This contact is exposed in the south end of the ridge separating the Bow valley from the much smaller valley of Bath creek.

116 m.
185·6 km.

One mile west of Laggan the railway leaves the Bow river and follows up Bath creek to the summit. Bow river continues toward the northwest, to its source in Bow lakes, 20 miles (32·2 km.) up the valley. The stream is enlarged by water from Hector lake. Mt. Hector (11,125 feet) (3,391 m.), with its castellated cliffs of Lower and Middle Cambrian formations, can be seen from the railway to the right of Bow valley.

121·5 m.
194·4 km.

In a quarry on the right of the railway there is a good exposure of Pre-Cambrian slates, in fresh condition. These shales and slates are transported to Exshaw, where they are used in the manufacture of cement. The purplish and drab color of these rocks is characteristic of the formation.

122 m.
195·2 km.

Looking ahead to the right can be seen the perpendicular cliffs of Mt. Daly formed in Middle Cambrian limestones, with a typical

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cliff glacier, a fragment of the large Daly glacier, on its eastern flank.

A few yards west of the crossing of Bath creek there is a good exposure of Cambrian basal conglomerate. It encloses fragments of the underlying slate, but the exact contact with the Pre-Cambrian is not visible along the railway.

122·2 m. 195·5 km. **Kicking Horse Pass** (The Great Divide)—Alt. 5329 ft. (1,625 m.). This is the continental divide. The pass, discovered by Sir James Hector in 1876, is a saddle-like depression about two miles broad carved out by the ice. The grade from the pass to the west into Kicking Horse valley is very much steeper than it is to the east into the Bow valley.

To the right of the pass is Mt. Bosworth in which there is exposed nearly 9000 feet (2743 m.) of Lower, Middle, and Upper Cambrian strata. The Bosworth section was examined by Walcott (**5**) in 1908, this being the first attempt to subdivide the Cambrian of the Canadian Rocky mountains into formations. From this point it will be seen that the structure in the western slope of the Rocky mountains represents the western limb of a monocline; whereas the Cambrian basal conglomerate is exposed near the divide, the rocks are Ordovician and Silurian in age in the last range to the west.

125 m. 200 km. **Hector**—Alt. 5,207 ft. (1,587 m.). The stream entering the lake at this point is Cataract brook. It drains Lake O'Hara and Lake McArthur, and glaciers on Mts. Victoria, Huber, Hungabee, Odaray, Cathedral and Stephen. Wapta lake at the right of the railway is the main gathering basin for the headwaters of Kicking Horse river. Below the end of the lake the river has cut a canyon through the Middle and part of the Lower Cambrian formations.

128 m. 204·8 km. From this point there is an excellent view of Yoho valley, a glacial U-shaped depression, which heads in the Yoho glacier. The valley

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is cut through Lower and Middle Cambrian strata. At Takakkaw falls, 1,248 feet (380 m.) high, the water cascades over Middle Cambrian limestone. The same formation causes the Twin falls, farther north in the valley, but the fall is not as great.

129 m.
206·4 km. **Upper end of No. 1 Tunnel.**

131·1 m.
209·7 km. **Lower end of No. 2 tunnel.**

Between the Pass and Field, a distance of about eight miles (12·9 km.), there is a difference in elevation of 1,160 feet (353·5 m.), of which 900 feet (274 m.) occurs within four miles (6·4 km.). To overcome this steep grade the Canadian Pacific railway has constructed two spiral tunnels. The upper one (No. 1), 3,200 feet (982·4 m.) long, is in Lower Cambrian quartzites in the base of Cathedral mountain. The lower one (No. 2), 2,900 feet (884 m.) long, is in Middle Cambrian limestones in the base of Mt. Ogden. There is a difference of 60 feet (18·3 m.) between the rails at the ends of the tunnel, in both No. 1 and No. 2. The average grade is now 2·2 per cent, whereas the grade of the old road, now used as a wagon road, is 4·4 per cent.

Before entering No. 2 tunnel, the glacier-shaped Kicking horse valley is seen, with its broad aggraded valley floor. On the left of the valley is Mt. Stephen (10,485 ft.—3,196 m.), and on the right is Mt. Field (8,645 ft.—2,636 m.).

132·5 m.
211·2 km. About one mile (1·6 km.) west of Cathedral station the railway passes through a short tunnel in Lower Cambrian quartzites. Between this tunnel and the wagon road there is a normal fault with about 3,000 feet (921 m.) displacement. Mt. Stephen is on the downthrow side, so that the Lower Cambrian quartzites in the Cathedral mountain come against the Eldon formation, at the top of the Middle Cambrian, in Mt. Stephen. This break has been called the Stephen-Cathedral fault.

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From this point there is an excellent view of Mt. Stephen. The base of this mountain is Lower Cambrian and it is capped by Bosworth formation (Upper Cambrian). The Cathedral formation extends to the top of the great North shoulder.

The Monarch mine is situated in Mt. Stephen about 1,000 feet (305 m.) above the railway in the Cathedral formation. The ore, consisting of lead and zinc sulphides, is a replacement deposit along a major and several minor fissures. A concentrating mill, on the left of the railway, has been recently constructed and is separating about 80 tons of ore per day.

The second short tunnel passes through the St. Piran quartzite in the shoulder of Mt. Stephen. The railway follows along the slope of the mountain, gradually approaching the level of the valley floor. At Field it is only 10 feet (3 m.) above the river.

137 m. **Field**—Alt. 4,064 ft. (1,239 m.). This
219·4 km. railway divisional point is the gateway to Yoho valley, Emerald lake and Ice River valley.

The famous trilobite fossil bed outcrops in the Ogygopsis shale about 2,600 feet (793 m.) above the railway on Mt. Stephen. Walcott [**6**] has determined 32 species of trilobita and brachiopoda from this lentile of shale. This shale belongs to the Stephen formation (Middle Cambrian.).

Another fossil bed recently discovered by Walcott occurs in the west slope of Mt. Field, in the "Burgess shale," which also belongs to the Stephen formation. This fossil bed is reached by Burgess pass and is shown in an illustration on page 177. From this shale Walcott [**7**] has determined trilobita, brachiopoda, merostomata, malacostraca, annelids, holothurians and medusae.

West of Field the beds dip more steeply to the west. A normal fault with the downthrow on the west side, passes between Mt.

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Stephen and Mt. Dennis. This is called the Stephen-Dennis fault.

Two miles (3·2 km.) west of Field the Kicking Horse river becomes a narrow channel and in one place passes under a natural bridge formed in the Upper Cambrian shales and slates.

3·5 m. 5·6 km. from Field.

Emerald—Alt. 3,895 ft. (1,188 m.). There are over 300 feet (91·5 m.) of Pleistocene lacustrine gravels along the sides of the Kicking Horse valley. The Canadian Pacific Railway Company has erected a gravel-washing plant at the station, the gravel being used for ballast after the clayey material has been washed out.

On the north side of the valley five distinct terraces can be recognized in these gravels along the valleys of Emerald creek and the Amiskwa river.

For the next four miles (6·4 km.) Kicking Horse river has a broad alluvial flood plain, nearly two miles wide in places.

Looking ahead to the right of the railway red-capped peaks and ridges in the Van Horne range are seen. These red-weathering shales, slates, metargillites and phyllites belong to the Chancellor formation of the Upper Cambrian, and overlie those beds exposed on the top of Mt. Bosworth at the divide.

On the south side of the railway in the Ottertail range, these shales and slates are overlain by the massive Ottertail limestone which forms precipitous slopes. The accompanying figure shows a gentle slope on the Chancellor shales and a very steep slope in the Ottertail limestone. Some of the peaks in this range are capped by Goodsir shale, the lowest formation in the Ordovician. The very sharp contact exposed in Mt. Goodsir in the Ice River valley, between the Cambrian, represented by the Ottertail limestone and the Ordovician represented by the Goodsir shales, is shown in another illustration page 180 (**8**). The fauna in those

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shales determine the age of the beds. Mt. Goodsir (11,676 ft.; 3,565 m.) is the highest in the Rocky mountains near the railway. A glimpse of this peak can be seen on the left of the railway at about five miles (8 km.).

Ottertail escarpment, showing Chancellor formation forming talus-covered, undulating surface; Ottertail limestone in cliffs; and Goodsir shales on gradual slopes.

8·2 m. 13·1 km. **Ottertail**—Alt. 3,696 ft. (1,127 m.). For some distance on either side of the station the railway cuts through highly sheared Chancellor shales and slates which are here characterized by their silken lustre and purplish gray color. The river now flows almost due south at the bases of Mt. Hurd and Mt. Vaux.

15 m. 24 km. The railway turns sharply through an angle of 120 degrees to the northwest around the end of a ridge of Upper Cambrian limestone. The river continues to the south for about two miles (3·2 km.) and then makes a similar sharp bend to the northwest. At this bend is Wapta falls, formed in the highly sheared, steeply tilted Upper Cambrian slates. The Beaverfoot valley extends to the left of the railway, and was the course followed by Kicking Horse river in pre-Glacial time. The stream course was diverted largely by morainal obstructions.

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17 m. 27·2 km. **Leanchoil**—Alt. 3,681 ft. (1,123 m.). Looking east along the railway, the Ottertail range lies in the background. Chancellor peak (10,751 feet, 3,276·8 m.) is especially prominent. Behind this ridge lies Ice River valley, in which is exposed the only igneous complex in this portion of the Rocky mountains. It covers about 12 square miles, has the form of an asymmetrical laccolith, and is alkaline in composition. This is one of the few localities in which sodalite is found in considerable quantities.

Between the second and third peaks to the left of Chancellor peak, the contact between the dark coloured igneous rock, (an ijolite), and the gray limestone can be seen from this point.

22·9 m. 36·6 km. **Palliser**—Alt. 3,283 ft. (1,001 m.). The highly sheared Goodsir shales outcrop at many places on either side of the railway. North of the station is a fault-line scarp on the shoulder Mt. Hunter. The up-throw has been on the northeast side so that the Upper Cambrian beds adjoin the faulted edges of the Lower Ordovician shales.

The glacial gravels are over 200 feet (61 m.) thick, and are frequently well terraced on both sides of Kicking Horse valley.

West of this point the valley narrows, and a canyon has been cut through steeply tilted Ordovician and Silurian beds in the Beaverfoot range.

28·4 m. 45·4 km. **Glenogle**—Alt. 2,991 ft. (911·5 m.). The best exposure of the black, fissile, Graptolite shales will be seen in the first small creek at the west end of the railway siding. This fauna is especially abundant in one thin layer of this formation. Throughout the remainder of the canyon the structure is complicated by faults and overturned folds. The Silurian beds are recognized as white quartzites and gray massive dolomitic limestones. This formation is highly fossiliferous in certain horizons.

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About one mile west of Glenogle there is a mineral spring in the Silurian dolomitic limestones. A yellowish calcareous deposit thickly coats the rock over which the water flows. Another spring rich in calcareous material, occurs about one mile farther down to the right of the railway. Some of the mineral spring water from this canyon has been tested and found to be rather strongly radioactive.

About half a mile east of Golden the valley of Kicking Horse river opens out into the Columbia valley. In the railway cut at this point there is a good exposure showing the gravels of the Columbia lying against the very steep side of the old valley along the western base of the Beaverfoot range. These stratified gravels extend at least 350 feet (107·5 m.) above the river.

35·6 m. 572 km. **Golden**—Alt. 2,580 ft. (786 m.). Kicking Horse river joins the Columbia river at this point.

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ANNOTATED GUIDE.

(Golden to Savona.)

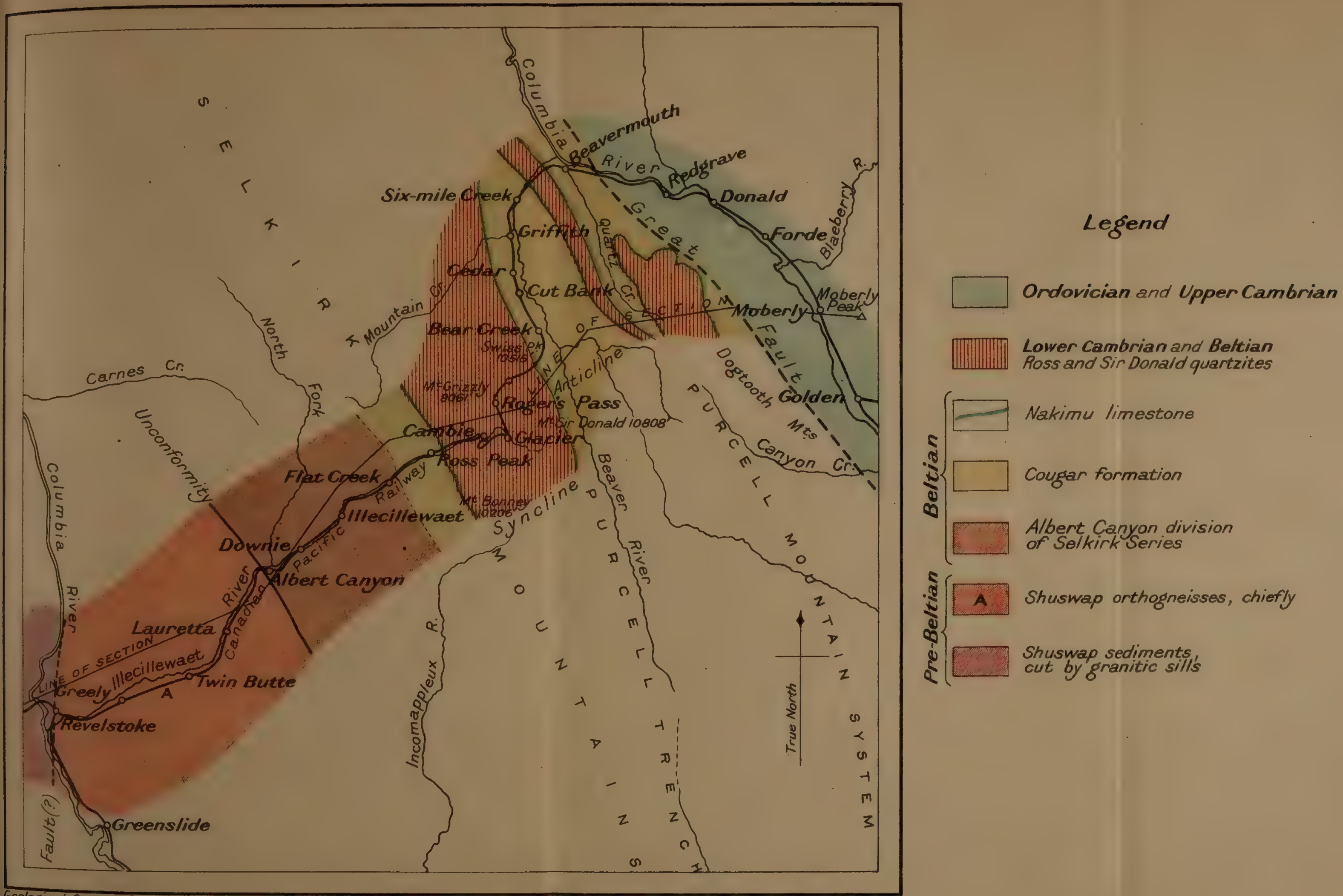
BY

Reginald A. Daly.

Miles and Kilometres.

35·3 m. 56·8 km. **Golden**—Alt. 2,578 ft. (786 m.). The train here enters a typical section of the Rocky Mountain trench, a through-going Cordilleran feature of a length hardly to be matched in any other mountain chain. About 100 miles (160 km.) above Golden is the source of the Columbia river, which, except for a short distance, occupies the main trench as far as the beginning of its "Big Bend", 87 miles (140 km.) below Golden.

The town overlies Ordovician shales; the long bastion-like escarpment of the Dogtooth range (Purcell Mountain system) across the valley is composed of the uppermost slates, schists, and quartzites of the Beltian series. The trench is, in fact, here located on a master longitudinal fault of a throw at least equivalent to the entire thickness of the Cambrian group (5700 m.). The fault plane runs close to the lower cliffs of the Dogtooth mountains. It has clearly located the trench, which, however, has been specially widened by erosion on the softer Paleozoic rocks ranging east of the great break. The fault probably dates from the Laramide (post-Laramie and pre-Eocene) revolution. The colossal denudation represented in the destruction of the uplifted Purcell block must have consumed much of Tertiary time. What part of the period was concerned with the excavation of the visible trough it is still impossible to say. The work was done in stages. In the later Tertiary the trench has been increased to widths of three to six miles (5 to 10 km.), a past-mature river



Route map between **Golden** and **Revelstoke**

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valley of first magnitude. Probably during the late Pliocene the region was uplifted and a narrower trough sunk in the old valley floor. Remnants of that floor are visible in the trench at elevations of 650 to 1,000 feet (200 to 300 m.) or more above the river. The bed-rock form has been seriously affected by Glacial erosion and deeply covered with drift, into which the Columbia has cut, with the development of terraces and a broad flood-plain.

The Pleistocene deposits are so thick and continuous in the trench that bed-rock crops out at the railway only twice between Golden and the 53rd mile-post, a distance of 28 kilometres. Practically as far as the observer at Golden can see on the southwest side of the trench, both north and south of the town, the rocks are silicious sediments of latest Beltian age. On the northeast side, the heights are chiefly composed of the Silurian (Moberly Peak) or Ordovician formations. After leaving Golden the first important exposure of rock at the railway track is on the right, at the crossing of Blaeberry river (45 mls.), where the Goodsir (Ordovician) shales are dipping at an angle of about 55° to the northeast. These, like all the other Paleozoic strata seen in the trench, are more or less crumpled and cleaved, indicating great disorder in this broad band followed by the trench. On the whole, however, the Cordilleran strike is preserved here, as it is all across the Middle ranges as far as Albert Canyon.

Purcell Mountain System.—The rugged wall on the west side of the trench is the northeasterly limit of the group of the high peaks here included in the Purcell system. As shown in the accompanying structure section, the rocks in this escarpment form the northeastern limb of a wrinkled syncline adjoining a well developed anticline along which the valley of Quartz creek has been excavated. The compound syncline has suffered intense glacial erosion, producing abundant alpine horns;

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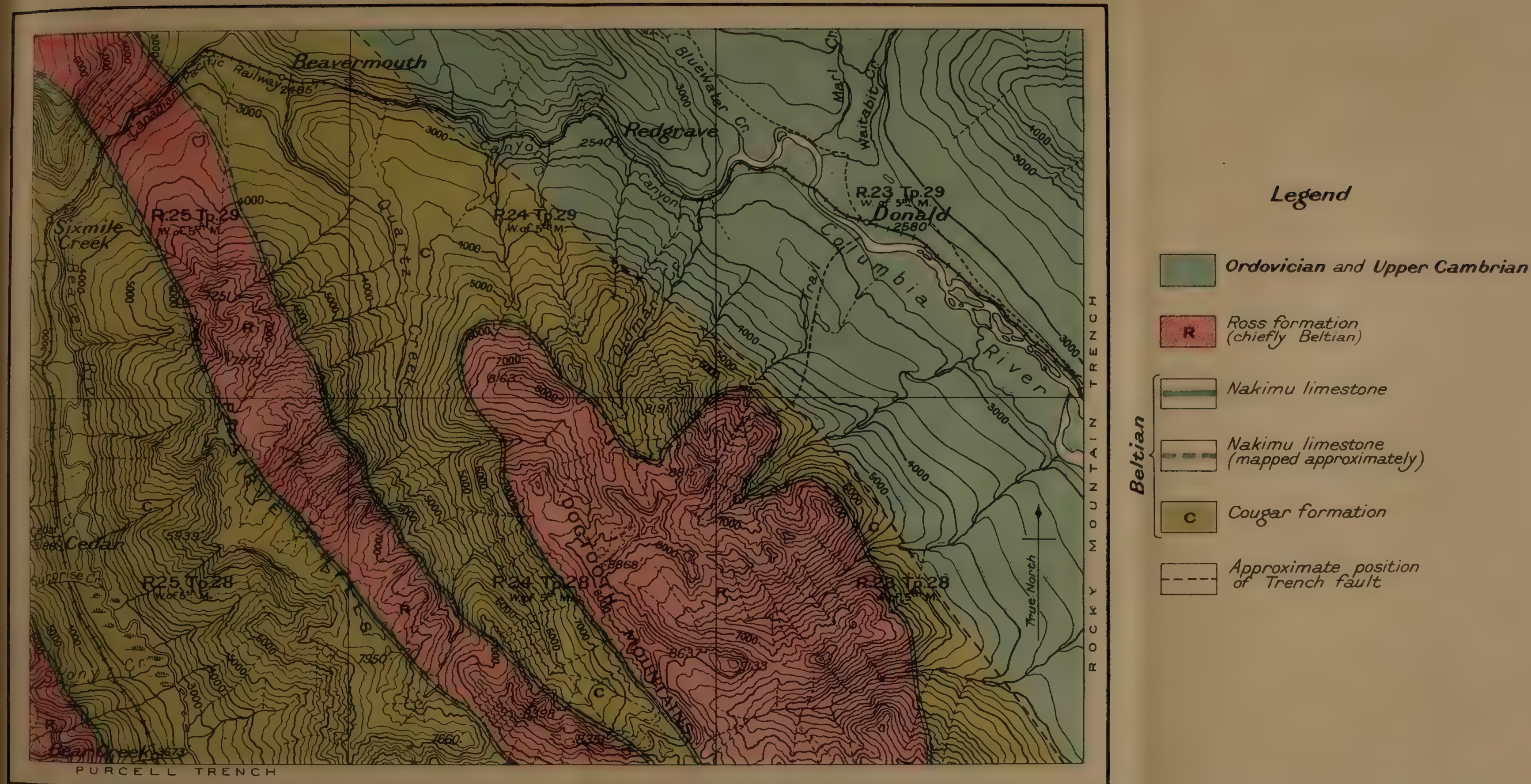
hence the appropriate name, Dogtooth mountains, for this division of the Purcells, situated between Quartz creek and the Columbia. A narrower, tightly compressed syncline forms the adjacent lower and less rugged range, called the Prairie Hills. That mountain group overlooks the broad Beaver River trough which, between Six Mile Creek (68·0 mls.) and a point many miles south of Beaver Creek (78·0 mls.), is an anticlinal valley excavated in the relatively friable rocks of the Cougar formation.

The Purcell mountain system is thus essentially a mass of Beltian strata folded with comparative regularity. The Cordilleran strike (here N. 30° W.) is generally well preserved throughout the whole area covered in this part of the Purcell system, as it is in the much broader section mapped at the International Boundary, far to the south. However, the folds show local disorder; they were accompanied by subordinate fractures and, where closely appressed, by mashing and by the development of slaty cleavage.

Three kilometres beyond Donald, soon after crossing the river, the railway enters a long series of rock cuts, where the river leaves the main trench, and is cutting a long canyon across the folded and mashed Paleozoics. On the right bank of the river, for a distance of many kilometres, is a mountain block separated from its structural equivalent, the Dogtooth range, by a late Glacial diversion of the river from the broad trench on the east. The Paleozoic shales and limestones, standing at high angles, can be seen in the walls of the canyon. Near the tunnel marked as 54·6 miles from Field, fossils of late Upper Cambrian age, including an *Illenurus* and a genus like *Dicellocephalus*, have been found in abundant calcareous nodules formed in shale and impure limestone.

The strata grow more and more disordered until the great Trench fault is reached, at a



Geological Survey, Canada.

Prairie Hills *and* **Dogtooth Mountains**

Miles

1 ½ 0 5 10

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5 4 3 2 1 0 5 10

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point about 3 kilometres east of Beavermouth station. There the Paleozoic shales and limestones abruptly cease and the train runs over the quartzites, slates, and schists of the Beltian Cougar formation. An exceptionally thick and massive quartzitic member of this formation soon appears in bold bluffs on the left; the same band of rock crosses the river at Beavermouth and continues on a N. 30° W. strike into the mountain to the right of the Columbia.

63·2 m. 101·7 km. **Beavermouth**—Alt. 2,430 ft. (741 m.), is situated at the confluence of Quartz creek and the Columbia river. The creek represents a case of stream diversion. Its former course lay to the eastward of the high mass of quartzite southeast of the station. Across that rock it had cut a narrow canyon about 1·2 kilometres in length and about 75 metres in average depth. Its floor is nearly 300 m. above the Columbia. Specially rapid (Glacial?) erosion on a band of fissile schists paralleling this quartzite on the southwest caused the diversion of the creek to its present course. The high-level canyon is now nearly dry and is open at both ends. Placer mining for gold has been carried on for some years along Quartz creek.

Two kilometres beyond Beavermouth the railway turns sharply away from the Columbia into the transverse valley of Beaver river, where the Prairie Hills syncline is exposed in a long succession of deep rock-cuts. The syncline is tightly closed. The first outcrops, seen where the railway first meets the Beaver, are cleaved quartzites and slates of the Cougar formation. These are often crumpled in detail but the general dip is about 80° to the southwest. At the 65·6-mile point the overlying Nakimu limestone, here reduced by shearing-out to a single vertical bed a few metres thick, is

65·8 m. 105·8 km. found. Close by is **The Gateway,** where the vertical Ross quartzites, forming the heart of the syncline, are well exposed. This is the only section where one has a good opportunity of seeing this important formation close

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at hand. Its habit is somewhat abnormal on account of unusually intense cleaving under tangential stress. Where seen outside this Prairie Hills syncline, the Ross quartzite is more massive. All or nearly all of the formation here exposed is of Beltian age; the younger, Lower Cambrian beds may not appear at this low level in the fold.

The southwestern limb of the syncline becomes identifiable at a point nearly 2 kilometres beyond the bridge over the river, where the Nakimu limestone with steep northeasterly dip crosses the railway. The train then runs over the Cougar formation with similar dips until, at a point about 2 kilometres beyond Sixmile Creek station, the dip becomes vertical or disordered. At that locality is the axis of the Beaver River anticline, trending N. 30° W.

Purcell Trench—As the train slowly climbs the steep grade to Bear Creek station, an excellent view of the Purcell Trench in its northern, relatively narrow development, is obtained. With remarkable straightness this primary feature of the Cordillera continues 40 kilometres S.S.E., to the head of the Beaver river and then down the Duncan to Duncan lake and the long Kootenay lake. The trench ends at Bonner's Ferry, Idaho, where it is entered by the transverse valley of the Upper Kootenay river. The total length of the trench is about 350 kilometres. West of it is the Selkirk Mountain system; east of it the group of ranges to which the inclusive name, Purcell system, has recently been applied.

Here in its northern part the trench is an erosion trough opened on the axis of a broad anticline which has been demonstrated for a distance of 30 kilometres and probably extends still farther south. At the International Boundary, the trench is considerably broader and is an erosion trough located on a longitudinal fault of the first order. Elsewhere, the origin of this depression has not been determined.

Miles and Kilometres.

The trench has been deepened and widened by Glacial erosion, with the resulting development of hanging valleys. The railway crosses several of these, in which the streams have already cut deep gorges in the schists and fissile quartzites. The walls of the trench, especially on the southwest side, are ornamented with scores of cirques, many being still deepened by living glaciers.

Excepting a few of the highest peaks, the entire mountain wall visible on the Purcell side of the trench is composed of the thick Cougar formation dipping steeply to the E.N.E. All the rocks in the lower slopes of the Selkirk wall belong to the same formation, here dipping steeply under the Nakimu limestone and the massive Ross quartzite, of which most of the highest peaks of the Selkirks are constituted.

78·0 m. **Bear Creek station**—Alt. 3,663 ft. (1116
125·5 km. m.). Below this point, near the confluence of Bear creek and Beaver river, the railway company is about to pierce a two-track tunnel, 7·5 kilometres (4·6 miles) in length. It will cross the main divide of the Selkirks and emerge at the railway loop near Glacier. One of the main objects of this boring is to cut out of the line of traffic the long chain of yet more expensive snowsheds now necessary between Bear Creek and Rogers Pass stations.

Beyond Bear Creek station the line turns up the creek and crosses the summit syncline of the Selkirk range. The upper beds of the Cougar formation and the Nakimu limestone are quickly traversed. On the left, above the forest of the canyon bottom, can be seen the thick rusty quartzites of the Ross formation, overlain by the gray, likewise massive, Sir Donald quartzite. The impressive horn of Mount Macdonald is composed of this youngest member of the Selkirk series, there forming an open, subsidiary syncline, which is continued into the still invisible peaks of Mt. Tupper on the north.

Mt. Tupper from Rogers Pass. Slopes underlain by Sir Donald quartzite.

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As the train emerges from the last snow-shed, the western limb of the sharp anticline, shown in the general structure section, may be seen on the left.

84·1 m. **Rogers Pass**—Alt. 4,302 ft (1,311 m.).
135·4 km. This station is situated on the axis of the main Selkirk syncline. The fold is here broken and faulted but the flat-lying beds of the axis can be seen, in clear weather, on the slopes to the north-northwest. The eastern limb is clearly apparent but the western limb is best exposed in the upper canyon of Bear creek. An oblique view of the subsidiary folds already passed over may be had toward the northeast, in the crags of Mt. Tupper.

The railway follows the axis of the main
87·3 m. syncline to **Glacier**—Alt. 4,086 ft. (1,245 m.).
140·5 km. Here the Illecillewaet and Asulkan glaciers are reached by good trails. The former drains the Illecillewaet snowfield (25 square km. in area) at its northern end, while the Geikie glacier drains it at the south. The Asulkan glacier is one of the several sheets heading on the rugged ridge culminating in Mt. Bonney. All of the glaciers are rapidly retreating, as illustrated in the accompanying figures.

The special map and section of this region, makes a detailed description of the local geology superfluous, but some remarks may be helpful.

The noble peak of Mount Sir Donald (10,808 ft.; 3,292 m.) to the southeast is composed of the Sir Donald quartzite, well jointed in sheets which from a distance deceptively resemble individual strata. The true dip of the quartzitic sandstone is to the E.N.E., at angles varying from 60° on the western slope to 15° or less at the eastern foot of the horn. Mount Sir Donald is, in fact, a remnant of a long,

Illecillewaet glacier in August, 1911. Photograph by H. Ries.

Illecillewaet glacier in August, 1912. Comparison with preceding figure shows recession of the ice-front during the year preceding. Photograph by H. Ries.

narrow, synclinal wrinkle adjoining the great Beaver River (Purcell trench) anticline. A subsidiary anticlinal axis, paralleling this syncline on the southwest, runs nearly through the crest of Eagle and Avalanche mountains and is probably coincident with the one just

Mt. Sir Donald from Eagle mountain; Mt. Uto in foreground. Photograph by Howard Palmer.

west of Mt. Macdonald summit. The western limb of this fold is also the western limb of the syncline followed by the railway from Rogers Pass to Glacier.

Another local anticline in the quartzite is well exposed near tree-line on Mt. Cheops and is continued across the Illecillewaet into Mt. Abbot. Some faults and numerous small slips, parallel to the general strike, have complicated the structure between Mt. Sir Donald and Cougar creek. On this account, and because of the close similarity of the Sir Donald

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and Ross quartzites, it has proved very difficult to map the exact contacts of these two formations. Nearly all the cliffs from the hotel seem to be composed of the Sir Donald formation. In spite of local complications, the upper valley of the Illecillewaet river, including the névé region, is to be considered as lying in the axis of the main Selkirk syncline. This view is substantiated by the easterly dip of the Nakimu limestone, exceptionally well exposed on Cougar mountain and Ross peak.

The character of the Sir Donald formation may be studied in the many large blocks strewing the floors of the valleys above the hotel. The essential similarities of the quartzitic sandstone, grit, and occasional conglomerate to the different phases of the St. Piran formation in the Rocky mountains (Lake Louise and elsewhere), are so many and so special that these formations have been correlated with much confidence. A general stratigraphic comparison, has in fact, referred the Sir Donald and the upper beds of the likewise unfossiliferous Ross quartzite to the Lower Cambrian.

A highly characteristic feature of all these formations is the abundance of bluish, opalescent quartz grains and pebbles, which are also found at many horizons in the Cougar formation, The source of this quartz is to be found in the coarse orthogneisses and pegmatites of the Shuswap terrane bordering the Selkirks on the west. The sometimes abundant feldspar grains in these sediments are microcline, microperthite, orthoclase, and acid plagioclases —all largely derived from the same source. Mineralogical composition, general stratigraphy, and field habit indicate that the Selkirk series represent the northern continuation of the thick Belt series of Montana and Idaho.

In the Selkirk mountains, there can be no doubt as to the conformity of the rocks here referred to the Lower Cambrian with the older, enormously thick mass of strata (Beltian system) to be seen between Ross Peak and Albert Canyon stations.

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From Observation point on Mt. Abbot one obtains an extended view in the heart of the Selkirk synclinorium. On the right and in front are the structural features so far noted. On the left, at the eastern end of Cougar mountain the Nakimu limestone is conspicuous in a steep rock-slope bare of vegetation. Farther west, to the limit of vision, the mountains are composed of the older Beltian strata, dipping monoclinally to the northeastward.

Leaving Glacier, the train descends to the "Loop", where the Selkirk tunnel will emerge at its western end. On the left a brief view is obtained of the Bonney glacier; on the right, a closer view of the gray Nakimu limestone on the western slope of the Cougar valley. One kilometre beyond the Cougar watertank, the limestone can be seen, continuing on the regional strike over the col between Green peak and Ross peak. The Caves of Nakimu (Caves of Cheops) are irregular tunnels occupied by Cougar creek in a subterannean part of its course along the limestone. Here we have the most westerly outcrop of this invaluable guide to the stratigraphy of the Selkirks.

For the next 5 kilometres the train runs over the Cougar formation, here distinctly more massive, homogeneous, and quartzitic than on the eastern slope of the Selkirk range. To right and left, heavy beds of white quartzite, interrupting the dominant, gray and rusty strata, can be seen. A narrow synclinal wrinkle affects the
95 m. general monocline about 1 kilometre west of **Ross**
153 km. **Peak station** and, in good light, can be discerned in the high bluff on the left.

Four kilometres beyond Ross Peak station (94·2 mls.), the quartzitic Glacier division of the Selkirk series conformably overlies the dark-coloured metargillites of the Albert Canyon division. The position of the contact between
98 m. these two contrasted formations can be seen
158 km. on the slope southeast of **Flat Creek station.**

From this contact, crossing the railway near

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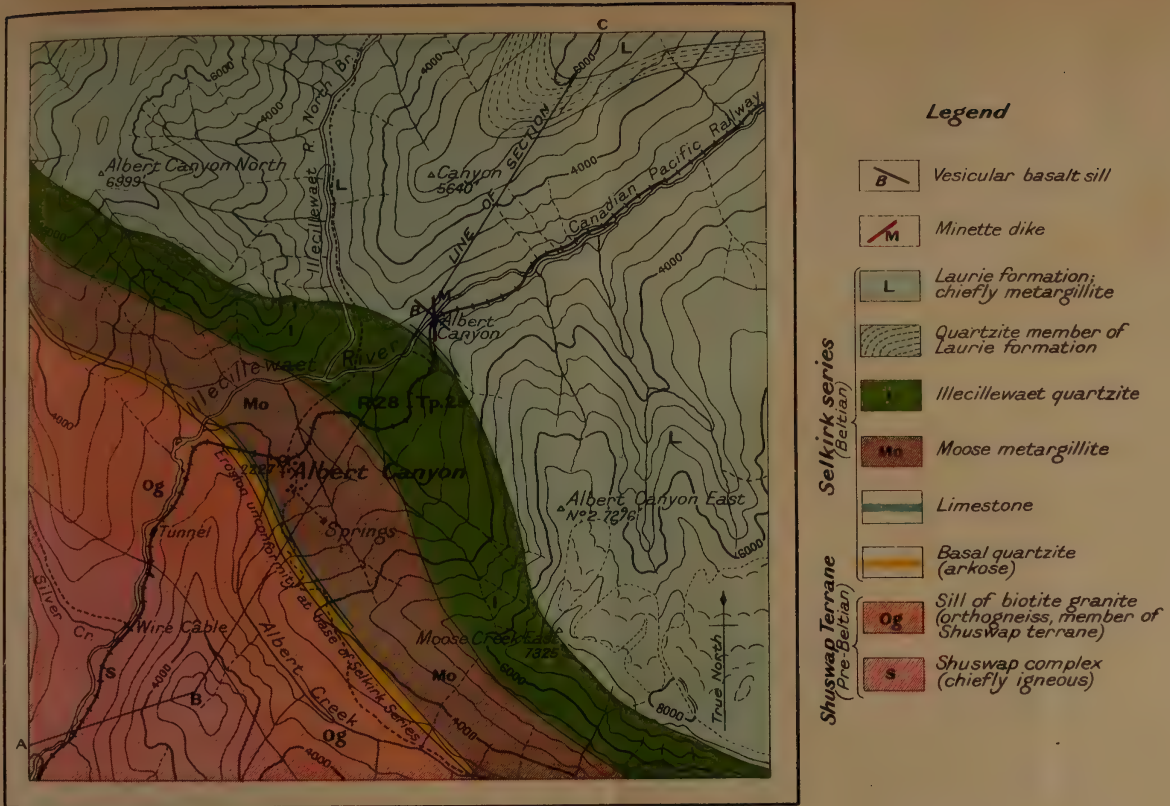
the 97th mile-post, to the Illecillewaet gorge, a distance of 10 miles (16 km.), the route crosses the northeasterly dipping beds grouped under the name, Laurie formation (See p. 134). Its apparent thickness is extremely great and, as yet, no evidence of large-scale duplication of strata has been discovered. Dawson considered that these beds have a synclinal structure, (G.M. Dawson, Bull. Geol. Soc. America, Vol. 2, 1891, p. 174), but detailed work has shown that they form a monocline accidented by rare, narrow strike-zones of crumpling. The most important of such zones is clearly visible from **Laurie station** (100·5 m.) in the long gulch due northwest of that point. Allowing liberally for all such evidences of repetition, the Laurie formation is still to be credited with a minimum thickness of over 4,500 metres.

From Flat creek to Illecillewaet (102·8 mls.; 165·4 km.) the dip averages about 50° to the N.E. The dark-gray to black, often highly carbonaceous and pyritous metargillites are well exposed in occasional long railway cuts. They are remarkably homogeneous for a nearly continuous exposure of 500 to 1,000 metres at a time. The principal variations consist in the alternation of more massive phases with the dominant fissile metargillite; rare, thin beds of carbonaceous limestone are found but the quartzitic interbeds noted in the columnar section do not crop out at the railway (see p. 134). Though the metargillite usually has a phyllitic appearance, this is not due to dynamic metamorphism. Schistosity and bedding are almost always parallel, and here as usual in the entire Selkirk series, the recrystallization of the original muds was accomplished under the static condition of deep burial, and before orogenic deformation.

At Illecillewaet (102·8 mls.) the dip has flattened to 10°—15° N.E., with local crumpling. The dip increases to 25° and then to 40° N.E. at



Geological Survey, Canada.

Albert Canyon

Miles: 1 ½ 0 1 2 3

Kilometres: 1 ½ 0 1 2 3

Section along line A-B-C

Miles and
Kilometres.

107·m.
172·2 km. **Illecillewaet Gorge** (Albert canyon)—Alt. ca. 2,450 ft. (747 m.). In the gorge an excellent view of the lower beds of the Laurie group is obtained. A thickness of about 200 metres is represented in continuous outcrop. A few thin lenses of blackish limestone and the basal 15-metre bed of light gray limestone (seen at the west end of the rock cut) are intercalated in the dominant metargillite. In the railway cut may be noted the only intrusive rocks known in our section between Glacier and Albert Canyon station. One of these is a narrow N-S. trending, nearly vertical dyke of minette, with small, completely altered, phenocrysts of augite. The other is a 1-metre sill of common, highly vesicular (!) basalt, which locally breaks across the bedding of the metargillite.

On the way to Albert Canyon station, a few rock-cuts in the Illecillewaet quartzite and Moose metargillite are passed. On the right the north branch of the Illecillewaet joins the main river.

109·4 m.
176·0 km. **Albert Canyon station**—Alt. 2,221 ft. (677 m.). A prolonged stop is made at this point for the double purpose of viewing the basal unconformity between the Selkirk series and the Shuswap terrane; and of becoming acquainted with an igneous phase of the latter series of rocks.

About 800 metres from the station, on the northwest bank of Albert (Moose) creek, the zone of unconformity has been laid bare for inspection. The high precipices visible on the east and north are composed of the dark-coloured strata of the Moose metargillite, Illecillewaet quartzite, and Laurie metargillite, dipping to the northeast. The Moose formation is largely hidden beneath the thick forest on the ridge due south but preserves its monoclinal attitude to the underlying limestone. This fine-grained marble is seen at the crossing of Albert creek, where

Miles and Kilometres.

it passes, by interbedding, into the "basal quartzite." (See p. 133).

The unconformity is here not marked by a conglomerate but by a fine-grained feldspathic sandstone, very similar in appearance to the altered orthogneiss beneath. The basal quartzite is interpreted as a statically (and dynamically?) metamorphosed arkose sand derived from the adjacent orthogneiss and washed but a short average distance from the parent, pre-Beltian ledges. It is practically impossible to indicate the exact plane of the unconformity, but it may be approximately located at the horizon where aplitic dykes cutting the orthogneiss cease to be visible in the quartzitic rock. The uncertainty is partly due to the intense static metamorphism of older and younger rocks alike; partly, to the deep weathering of the orthogneiss before it was covered by the bedded arkose. Microscopic study shows that, for depths of 60 to 75 metres stratigraphically below the surface of unconformity, the orthogneiss has been thoroughly altered. This alteration is apparently only explicable as due to profound secular weathering preceding deep-burial metamorphism.

Opportunity will be afforded for a more extended study of the orthogneiss itself. It has the form and relations of a broad laccolith or sill, with a thickness of 1000 metres for the part still remaining after the Beltian erosion. Along the railway the mass can be well seen to show a persistent gneissic structure which is closely parallel to the bedding and fissility of the overlying Beltian strata. The lower contact of the sill crosses the railway at a point about 2000 metres west of Albert Canyon station. There the ancient granitic magma was clearly intruded along a plane parallel to the banding in dark schists probably in part of sedimentary origin. These bedded Shuswap rocks and the great intrusive sheet evidently lay nearly horizontal while the Beltian strata were being deposited upon them. Their flat position was typical

Orthogneiss near Albert Canyon station, schistosity due to static metamorphism.

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of the rocks of the Shuswap terrane until the revolution which flexed the Rocky Mountain Geosynclinal into the folds of the Selkirk range.

The thoroughness of the static metamorphism suffered by the orthogneiss is very striking. In part the completeness of the recrystallization of the granite may be explained by burial under the enormous mass of geosynclinal sediment, but it should be noted that similar metamorphism is shown in the Shuswap orthogneisses far to the west where the Beltian-Cambrian strata were, apparently, never deposited in great strength. It seems probable that the advanced static metamorphism of the older Shuswap rocks was already accomplished in pre-Beltian time.

At this section along the railway track, one can see samples of the many aplitic and pegmatitic dykes cutting the orthogneiss and schists beneath it. The abundance of these igneous intrusions here, together with their entire absence in the adjacent Beltian strata, is one of the leading proofs of an important erosion unconformity at the base of the Selkirk series.

From the 110th mile-post, near Albert Canyon, to Shuswap station, 116 miles (186·7 km.) farther west, the railway runs almost entirely over the Shuswap terrane. For the first 30 kilometres the line crosses a dominantly igneous phase of the formations composing this second principal province of the Canadian Cordillera. Biotitic and hornblendic orthogneisses are the chief rock types until the Columbia river at Revelstoke is reached. These metamorphosed granites are all pre-Beltian but show different dates of intrusion. The oldest masses observed are generally hornblendic and are sills cutting coarse sedimentary (?) mica schists; or are larger bodies (batholiths?) without clear indication of shape. The hornblendic granites seem to have been statically metamorphosed into gneisses at an early date, for the younger,

Map showing approximate distribution of the Shuswap terrane rocks in south central British Columbia.

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generally biotitic orthogneisses characteristically occur as sills following a pre-existent, flat-lying foliation in the older rocks. The abundant masses of the later group were themselves rendered gneissic by a similar type of metamorphism and then injected by myriads of thinner sills, dykes, and chonoliths of white or pink pegmatite and aplite. These youngest members of the complex are less affected by metamorphism, though a gneissic structure parallel to sill-contacts is often seen also in them.

The whole assemblage of rocks is in striking contrast to that in a normal batholithic province of a post-Cambrian date of intrusion, and one cannot but suspect that some of the conditions of rock formation in this typical "Archean" field were peculiar to an early epoch in the earth's history.

The gneissic complex is not well exposed in the Illecillewaet valley except in a few places where forest fires have bared the ledges. An

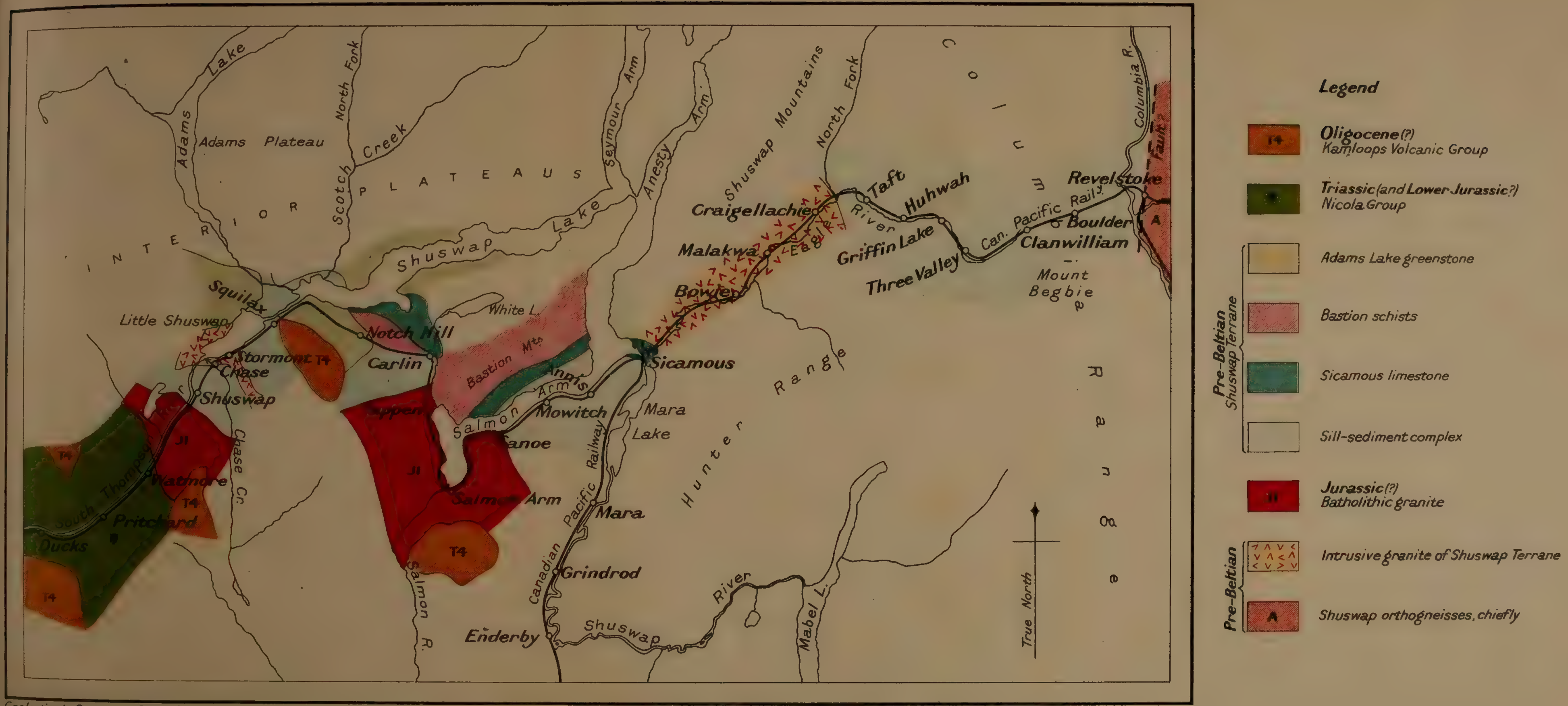
119·6 m.
192 km. **Twin Butte Station**
Greely Siding

example is seen on the left, for several kilometres between Twin Butte station and Greely siding (124·2 mls.; 199·5 km.).

Near the 128th mile-post the river cascades over schists and gneisses on which it has been locally superimposed through its own alluvium. At this point is the power plant of Revelstoke. As the train turns sharply to the right, one sees the fore-set beds of the delta built by the Illecillewaet into the Columbia valley when it was here laked, with a water level about 70 metres above that of the present Columbia. It is probable that this water-body was a great expansion of the existing Arrow lakes.

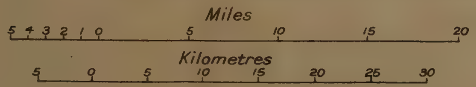
130·3 m. **Revelstoke**—Alt. 1,492 ft. (455 m.) an
209·7 km. important distributing centre in the interior trade of southern British Columbia.

The orthogneisses, aplites, and pegmatites can be easily studied on the mountain slope rising directly from the railway yard.



Geological Survey, Canada

Route map between **Revelstoke** and **Ducks**



Miles and Kilometres.

The town lies in the '*Selkirk Valley*,' namely, that part of the Columbia river valley which bounds the Selkirk mountain system on the west and separates it from the long Columbia system, which across the valley rises to heights approaching 9,000 feet (2,743 m.). This long depression has a complex history and is of composite origin, though the details of neither have been worked out. Over most of Revelstoke mountain, north of the town, the strikes average about N.N.W.—S.S.E., a Cordilleran direction corresponding probably to fault-blocking during one of the post-Cambrian periods of mountain-building. Across the river the strikes average nearly E.—W. At its eastern bank, 5 kilometres above Revelstoke, these structural lines are found in close proximity, indicating a N.—S. fault on which the river is located. Other local evidence agrees with the view that this part of the Selkirk valley has been formed by erosion on a longitudinal fault of unknown but possibly considerable throw. The downthrow is probably on its eastern side.

Along the branch railway to Arrowhead, 44 kilometres southward from Revelstoke, one may observe the prevailing low dips in the Shuswap terrane.

From Revelstoke to Kamloops the mile-posts are numbered in a new series, beginning in the east, and distances are stated accordingly.

At the crossing of the river one notes its increase of size, accomplished in its 300-kilometre journey from Beavermouth where it was last seen. In that distance the river has rounded the northern end of the Selkirk range, and it is here flowing south toward the lava fields of Washington State. After running over one of the terraces characteristic of this valley, the train reaches some extensive artificial cuts in the *Tonkawatla paragneiss*. (See page 123.)

The normal orthogneisses, developed as thick sills and many dykes cutting the sediments and problematic basic schists, begin to appear as the low divide of the Columbia range is approached, near Clanwilliam.

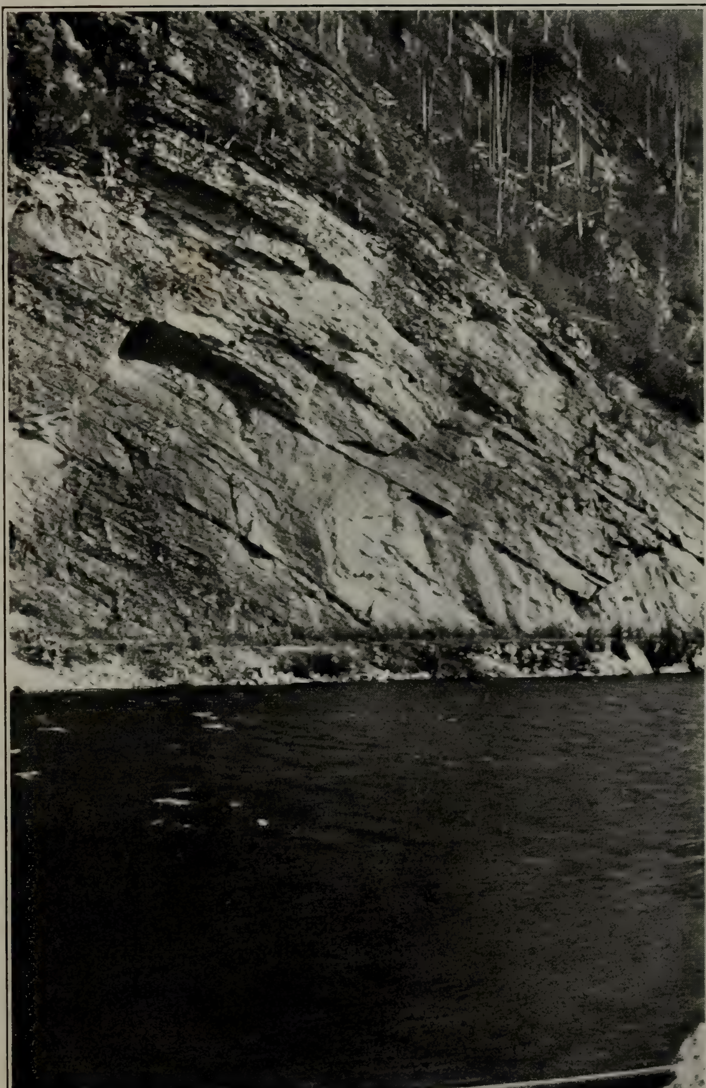
Miles and Kilometres.

8·9 m. 14·2 km. from Revelstoke. **Clanwilliam station.**—Alt. 1,812 ft. (552 m.). The rock-cuts here afford excellent exposures of a dominantly sedimentary phase of the Shuswap terrane. Paragneisses, mica schists, quartzites, and subordinate limestones (cut by granite sills) are flexed into an anticlinal fold pitching to the west. Tonkawatla creek and the deep col at the divide are located in the heart of this fold. The stratigraphic place of the sediments in the Shuswap series is not clear. The older beds are much like the Tonkawatla formation, and the quartzites have striking resemblance to the Chase formation exposed near Shuswap village. The still younger mica schists overlying the quartzite may represent the Salmon Arm formation. (See p. 124.)

At the western end of Victor lake, 2 kilometres west of Clanwilliam, a 200-metre sill of biotite granite has been thoroughly sheared and its femic constituents, especially the mica, have been segregated in thick, black bands. This strikingly banded orthogneiss is a result of *dynamic* metamorphism which is comparatively seldom exhibited in the Shuswap terrane.

14·7 m. 24·8 km. From **Three Valley station** to Sicamous (45·1 mls.) the line runs through a field of orthogneisses cutting rarely exposed, rusty mica schists, probably of sedimentary origin. Strong jointing and the fissility of the schists are conditions which have led to extensive land-slides, visible at and for some kilometres beyond Three Valley.

21·1 m. 33·8 km **Mitikan Siding**—Alt. 1,300 ft. (396 m.). To the south may here be seen a high bluff seamed with many pegmatitic and aplitic sills. From a more commanding position their number in this slope has been estimated to exceed two hundred; their thicknesses range from 1 metre to about 200 metres. They cut rusty crystalline schists which are in part sedimentary, enclosing occasional thin beds of limestone.



Quartzites, mica schists and paragneisses, showing coincidence of bedding and schistosity; Shuswap series. At Summit lake, Columbia range, in railway section.

Miles and Kilometres.

From Taft station (24·5 mls.) nearly to Sicamous the line runs over massive orthogneiss generally rich in hornblende and thus contrasted with the dominant biotitic gneisses of the Shuswap terrane. Near Taft the hornblende gneiss is in sill relation to the rusty (metasedimentary?) schists, but beyond Craigellachie (28·5 mls.) it seems to have the continuous character of a batholith or extremely thick laccolith.

Approaching Sicamous, the train crosses the delta of the Eagle river which has grown so far as to nearly isolate Mara Arm from the main Shuswap lake.

45·1 m. 72·6 km. **Sicamous**—Alt. 1,147 ft. (350 m.). The Shuswap lakes have a total length of about 150 kilometres. They represent profound changes in the drainage system under the influence of Pleistocene glaciation. Not only were water-divides and stream directions modified at that time; the graded valley-floors were converted by Glacial erosion into series of rock basins. Drift barriers have also co-operated in the formation of these fiord-like lakes. The greatest depth recorded for the Shuswap lakes is 447 feet (136 m.), measured about 11 kilometres north of Sicamous. The neighbouring Adams lake, 70 kilometres long and 1,200 feet (366 m.) deep, is a pure type of rock basin. Part of its floor is almost at sea-level.

From Sicamous the excursionists will obtain their first view of the Belt of Interior Plateaus here merging into the more rugged Columbia range just traversed. The origin of the upland facets of these plateaus is a problem not yet completely solved. As a whole, however, they represent a late Miocene or early Pliocene land surface, dissected by streams revived because of the general Cordilleran upwarp during the Pliocene period. (See pp. 162-164.)

At and west of Sicamous station a partial section of the Sicamous limestone (p. 124) may be studied. It occurs in a fault-block showing the exceptional Cordilleran N.W.—S E. strike,

View in belt of Interior Plateaus looking westerly down Shaswap lake near Blind bay.

Miles and Kilometres.

with northeasterly dip. As one goes westward he descends in the series and finds the limestone becoming increasingly charged with sills of orthogneiss and aplite. Near the 47th mile-post the limestone is apparently underlain by a massive quartzite interrupted by films and thin beds of coarse muscovite schist. This may represent a siliceous member of the Salmon Arm formation or else the younger Chase quartzite. The coarseness of the mica schist and the massiveness of the lowest beds of limestone are explained by the thermal metamorphism exerted by the abundant sills. In the southeastern slope of Bastion mountain across the lake, the coarse, glittering (Salmon Arm) mica schists cut by many granitic sills pass up gradually into a fine-grained metargillite almost free from intrusives, and the latter rock is conformably overlain by the normal, fissile Sicamous limestone.

One of the best exposed sections of the Shuswap series is that exhibited as a great monocline from Canoe point, along the western shore of the lake, to Cinnemousun narrows, 23 kilometres distant. Green schist and massive limestones, corresponding to the youngest recognized members of the Shuswap series, are found near the narrows and at the top of this northerly-dipping monocline. The rocks on the opposite shore of the lake, north of Sicamous, are largely orthogneisses and have attitudes usually quite different from those of the monoclinal section. The valley of this part of the main lake therefore seems to be located on a fault with downthrow on the west.

From the limestone band just west of Sicamous to the 56th mile-post the line crosses the Salmon Arm schists injected with many sills and dykes of orthogneiss, pegmatite and aplite.

At 56·2 miles (90·4 km.) a large rock-cutting shows a coarse porphyritic syenite, which crops out again at the southwestern base of Bastion mountain nearly due west, across the lake. This rock appears to be a peripheral phase of

Miles and Kilometres.

a batholith extending southward and westward for many kilometres and northward a short
71 m. distance beyond **Tappen station.** The central
114·2 km. and greater part of the batholithic mass is composed of biotite granite. Like the syenitic phase, it is massive, relatively little crushed, and lacking the multitude of pegmatitic injections so characteristic of the Shuswap orthogneisses. This batholith thus seems to be of post-Shuswap date and it is tentatively referred to the late Jurassic period of granitic intrusion.

The bold bluff of Bastion mountain north of the Arm is composed of the Sicamous limestone dipping 28° to the N.W. The limestone forms a continuous band along the southern face of the mountain to the shore of the main lake north of Canoe point, and 15 kilometres from the bluff overlooking Tappen.

Looking southward from Salmon Arm, a thick cap of Tertiary lava (basalt and augite andesite of the Kamloops groups), unconformably overlying the granite, is seen in Mt. Ida. This is the first of many similar remnants of these Oligocene (?) volcanics to be encountered in the railway belt. (See page 148.)

As the train leaves Tappen and climbs the grade to Notch Hill station, the dark Bastion schists overlying the Sicamous limestone may be observed occasionally across the valley.

80·1 m. **Notch Hill Station**—Alt. 1,685 ft. (513 m.).
128·9 km. At this point the line is crossing greenstones and chloritic schists, representing the volcanic Adams Lake member of the Shuswap series (page 124) or else much metamorphosed intrusives of the same general epoch. The Blind Bay valley is floored with the Sicamous limestone presumably repeated here by a strike-fault. The ridge southwest of Notch Hill is composed of a second outlier of the Oligocene(?)
87·8 m. lava-field. Near **Squilax station** the railway
144·5 km. touches the unconformity between this volcanic cap and the Shuswap green schist formation. Here the growing delta of Adams river draining

Miles and Kilometres.

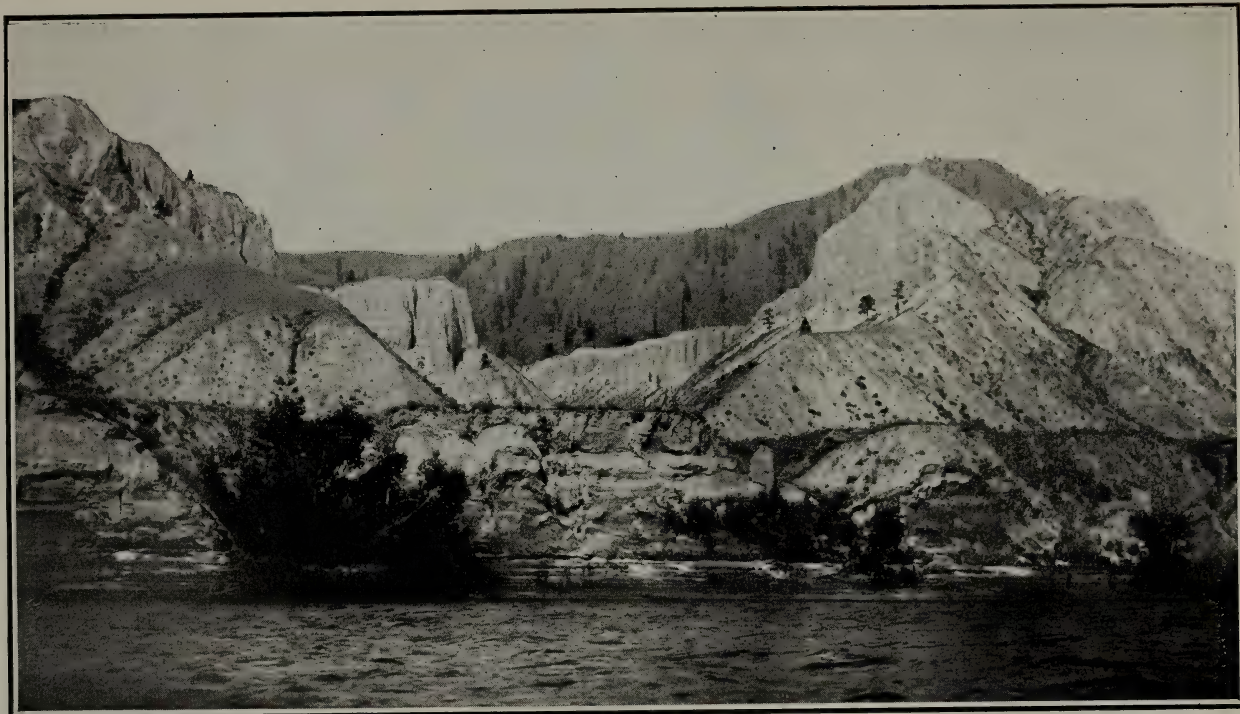
the long Adams lake can be seen to separate the main Shuswap lake from Little Shuswap lake.

The smaller lake basin has been eroded in Shuswap orthogneiss with the form and relations of a large irregular laccolith cutting the Chase quartzite and coarse mica schists of the same habit as that characterizing the Salmon Arm schists thermally metamorphosed. The laccolith is itself gneissic. Its planes of schistosity, like its contacts and the invaded sediments, dip 55–60° to the N.N.W. The E.N.E. end of the body is near Squilax; the W.S.W. end appears on the ridge across the river from Shuswap station. Where observed, the upper contact of the laccolith is made with the Salmon Arm(?) schists or with (intrusive?) greenstone of Shuswap age. The schists below the lower main contact are heavily injected with ortho-
91·9 m. gneiss sills, and at **Stormont siding** the massive
147·9 km. orthogneiss cross-cuts the sediments as a very broad dyke extending southeastwardly through the mountain. This 'dyke' may represent the main feeder of the laccolith.

Between Chase (94·0 m.—151·3 km.) and Shuswap station (95·9 m.—154·3 km.), the line nearly parallels the strike of the coarse Salmon Arm schists. The cliffs east of Shuswap are composed of the underlying, massive Chase quartzite dipping 50° to the N.N.W. (See page 123).

A short distance beyond this station the sediments are truncated by a homogeneous granite, little strained and with other characteristics of the post-Paleozoic (late Jurassic) batholiths. With its abrupt appearance the section leaves the Shuswap terrane.

Terraces become more and more prominent features in the valley floor. Their material is remarkably fine-textured, homogenous silt, showing distinct, even, bedding. As Dawson recognized long ago, it is clearly a lacustrine deposit and dates from the late Pleistocene. Since the silt was not deposited in the basin of Little Shuswap lake, it is most probable that that



Silt terraces on South Thompson river, with Pennsylvanian formations (Cache Creek series) in the back ground. Looking north from a point about three miles above Kamloops.

Miles and Kilometres.

basin was closed by a thick valley glacier at the time of silt deposition. The valley was similarly dammed by a large, local glacier entering from the valley of the North Thompson. Throughout the distance from Shuswap nearly to Kamloops—50 kilometres—the valley of the South Thompson was thus laked, and fine, white silt was accumulated to depths greater than 120 metres.

Nine kilometres beyond Shuswap station, the western contact of the granite is reached. It is here intrusive into the rocks of the Nicola series, in which the valley of the South Thompson river is sunk for a distance of 19 kilometres (102 mls. to 118 mls.)

The first rocks of this series to be crossed constitute a thick well-stratified body of hard sandstones and fine-grained strata shown to be in part bedded volcanic ash, but probably in part true argillites. Subordinate volcanic breccias of basic composition are interbedded. The whole forms the youngest local phase of the Nicola series conformably overlying the massive lavas of the Triassic, and is itself either upper Triassic or Jurassic in age. The dips here range from 60° to 80° to the east, indicating an apparent thickness of more than 2,000 metres for this stratified member.

104 m.
168.6 km. Just beyond **Pritchard siding** is its (lower) contact with the very massive lavas of the Triassic Nicola series (see p. 145). These can be well seen in dark coloured bluffs across the river. Their structure is extremely difficult to decipher. Pyroclastic beds are rare; thick flows (and sills?) of basaltic lava are dominant. Wherever the dips can be observed they are steep, generally 50° to 90°, with strikes ranging from N.-S. to N.W.-S.E.

To right and left the distant summits are capped by Tertiary basaltic lavas (Kamloops group) with associated fresh-water sandstones. These have low dips and overlie the more massive, more deformed, and more altered Triassic volcanics unconformably.

Miles and
Kilometres.

111·9 m. **Ducks station**—Alt. 1,146 ft. (349 m.). At
180·1 km. this point the Nicola rocks are specially well seen, across the river. Three kilometres to the south-east, the Tertiary lavas are now dipping at angles varying from 45° to 90°, indicating the local vigour of the last orogenic deformation (late Miocene) in British Columbia.

At and beyond Ducks station, the silt terraces are very conspicuous.

At the 118th mile-post, nine kilometres beyond Ducks, the Triassic series can be seen north of the river, resting on the Carboniferous (Pennsylvanian) limestone, the light gray colour of the latter contrasting well with the deep tint of the Nicola lavas. The relation is that of unconformity, since the lavas are underlain by a basal conglomerate containing chert pebbles derived from the limestone. The conglomerate and the plane of unconformity dip east at an average angle of about 50°, The limestone has a variable attitude but also dips at a high angle to the eastward. The agreement seems to show that the pre-Triassic deformation of the Carboniferous strata was not severe.

This is one of the best exposed contacts between these two great series yet found in British Columbia.

Continuing to Kamloops, the route crosses the Carboniferous rocks. (See p. 144). The dark-coloured ledges are chiefly composed of cherty quartzites and altered argillites, but some basic volcanic ash and coarser pyroclastic material is also interbedded. At intervals, light gray vertical bands represent as many occurrences of older fossiliferous Pennsylvanian limestone. The general structure north of the river, through to the North Thompson river, is the monoclinal. The strike averages N. 35-40° W.; the dip, 75-80° to the N.E. Yet there are a few local reversals of the always steep dip, and it is likely that the total thickness calculated from

Miles and Kilometres.

the generalized monocline is deceptively great. Nevertheless, a minimum thickness of 2500 metres of Pennsylvanian beds seems to be represented. It is improbable that pre-Pennsylvanian formations occur in this section.

122·1 m. 207·8 km. **Kamloops**—Alt. 1,151 ft. (351 m.)—is another important distributing centre for the interior trade of the province. Its location was determined by the confluence of the South Thompson and North Thompson valleys; the one followed by the existing Canadian Pacific Railway, the other now witnessing the completion of a second transcontinental line (Canadian Northein Railway). Since leaving Little Shuswap lake the country has become rapidly drier and Kamloops is the centre of a scattered farming and grazing community largely dependent on irrigation facilities.

Beyond Kamloops the mile-posts begin a new sequence of numbers; distances will be stated accordingly.

Just outside the western limit of the town the railway crosses a band of massive traps referable to the Nicola series. These are unconformably overlain by low-dipping Tertiary (Oligocene?) lava flows and tuffs, containing the fossiliferous Tranquille sandstones and shales (see p. 149). These can be seen on both sides of the river delta now growing rapidly into Kamloops lake through the activity of the silt-laden river. The Tertiary sediments

8·0 m. may be seen, on the left, at **Tranquille Siding.**

12·8 km. Just beyond that point the line skirts the long cliff called "Cherry Bluff." The massive rock composing it is a sheared and greatly altered mass of variable, dioritic to monzonitic and even gabbroid nature. The body is 8 kilometres long and 4·5 kilometres in maximum width. The lake lies in its major axis and the replica of Cherry Bluff is to be seen in "Battle Bluff" across the water. The granular rock is clearly intrusive into the Nicola traps, which form part of its roof both north and south of the lake. The relation to the Tertiary series is

Miles and Kilometres.

not so obvious. The Oligocene (?) lavas and sediments dip away from the intrusive on all sides, as if the intrusive were a partially unroofed laccolith of later Tertiary date of intrusion. One difficulty standing in the way of full belief in this hypothesis is the advanced shearing and alteration of the intrusive; a similar condition is extremely rare in the post-Oligocene intrusives of the Cordillera. According to a second interpretation the laccolith dates from the Triassic, representing a late phase in the eruptivity of that period. On this view the shearing of the intrusive and the deformation of the Tertiary rocks would be explained by a post-Oligocene, orogenic doming of the whole complex of solid rocks.

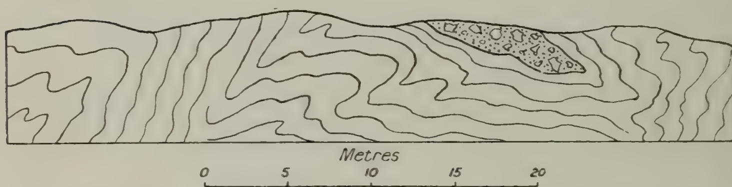
14·6 m. 23·4 km. **Cherry Creek station.**—Alt. 1,134 ft. (346 m.). Here the southeastern contact of the great intrusive is crossed and the line then runs continuously over the Triassic (Nicola) traps (with fossiliferous interbeds of limestone) to Savona (25·3 m.—40·7 km.).

19·7 m. 32 km. At **Munro Siding** the "Painted Bluffs," east of Copper creek across the lake, are in full view. These are composed of brilliantly coloured Tertiary volcanic rocks. The Tranquille tuff beds which underlie the basaltic lavas of the Kamloops group, vary from pale buff or dull green to dark red, brown or gray in colour, and are largely altered. Plant and fish remains are found in these beds which place them provisionally in the Oligocene. The sequence of the lavas and pyroclastics on the north side of the lake is almost identical with that exposed on Savona mountain on the south side. It is thought that the sections are on the limbs of a broad anticlinal dome since bevelled off during a Pliocene erosion cycle. The surface resulting is well preserved on both Hardy and Savona mountains.

West of Copper creek, on the hillside may be seen the sites of cinnabar mines which have produced 7,000 lbs. (3,175 kg.) of mercury. The cinnabar is associated with small quantities of stibnite and has a calcite-quartz gangue.

The ore is found in irregular veins traversing an altered, now dolomitic greenstone containing pyroxene and olivine.

The silts forming occasional benches on the shores of Kamloops lake are often seen to have been crumpled by overriding ice which occupied the valley during a temporary increase of glacial activity in the late Pleistocene.



Section illustrating great crumpling of Glacial silts by advancing ice sheet which deposited typical till on the silts. Locality 3.5 km. west of Cherry Creek station.

WESTERN PART OF THE BELT OF INTERIOR PLATEAUS.

(SAVONA TO LYTTON.)

BY

CHARLES W. DRYSDALE.

ESSENTIAL GEOLOGY.

INTRODUCTION.

That portion of the British Columbia Cordillera which lies between the Columbia Mountain system on the east and the Coast range on the west, is known as the Belt of Interior Plateaus. It is with the section between Kamloops lake and Lytton, along the course of the Thompson river which traverses this belt, that the following outline of geology deals.

The district was first examined geologically in 1877 by G. M. Dawson [**1**] and again by him in a more detailed

manner during the summers of 1888, 1889, 1890. The results of his work are contained in the Report on the Kamloops Map Sheet [**4**].

Physiography.

As viewed from the wide, open valley of Thompson river, the Kamloops district presents a hilly and even mountainous relief, the bordering summits rising from 4,000 to 5,000 feet (1,200 to 1,500 m.) above the level of the river. A broad summit view, however, explains why it is included among the Interior Plateaus of British Columbia, for from about the 4,000-foot (1,200 m.) level, there stretches as far as the eye can see a series of gently undulating and plateau-like upland surfaces. Within the upland, the younger valleys appear to be deeply entrenched.

Both the annual and daily range of temperature is great. On account of the very slight rainfall, the region is commonly known as the "Dry Belt of British Columbia."

Where irrigated, the semi-arid land of the valleys, commonly covered with sage brush, cactus, scattered yellow pine, and thickets of poplar, is very productive of fruits and vegetables. The grassy "park country" of the upland affords good grazing for cattle, and a supply of timber for the ranches.

For the explanation of relief in the district at least three cycles of erosion must be considered: one in Cretaceous; one in pre-Miocene; and the latest in Pliocene time. It is to the Pliocene erosion cycle that the present upland topography chiefly owes its development.

The facts upon which the above tentative conclusions are based are as follows:—

1. Early Tertiary (Eocene ?) conglomerates rest directly upon the upper Jurassic batholith south of Walhachin. The conglomerate is largely composed of well water-worn boulders of granite and Paleozoic metamorphics. As granite batholiths consolidate under considerable thicknesses of superincumbent material, such conditions would necessitate the removal by erosion of the entire cover from the batholith. A great thickness of rock must, then, have been removed during the Cretaceous period.

2. The absence of Upper Cretaceous rocks in the district, and the entire absence of Cretaceous rocks east of

Ashcroft would imply continental conditions and consequent erosion during at least late Cretaceous time.

3. South of Kamloops lake at an elevation of about 2,000 feet (610 m.) an extensive flat is underlain by Jura-Triassic rocks, and entrenched by an early Tertiary river valley. The old river valley is filled with Coldwater conglomerate, sandstone, and shale dipping at low angles. The rocks of this formation form prominent strike ridges which rise high above the flat referred to, and form, at the contact, a topographic unconformity. The flat is a conspicuous topographic feature, and is thought to represent a remnant of an old uplifted Cretaceous erosion surface since modified by Glacial action. Here, through favourable tectonic conditions, a portion of the Cretaceous erosion surface has been preserved to the present time and dominates the topography.

4. The next erosion cycle provisionally referred to pre-Miocene and post-Eocene time, is evidenced by a marked unconformity between early Tertiary formations and lower Miocene (?) volcanics. Near Ashcroft, as elsewhere throughout the Belt of Interior Plateaus, the early Tertiary formations are strongly uptilted, and they have been apparently subjected to crustal disturbances prior to the later vulcanism. Such orogenic movement would naturally inaugurate a new cycle of erosion which probably removed vast quantities of the loose continental deposits of early Tertiary age.

5. The third and most important erosion cycle which is thought to have largely developed the present upland topography, continued into the Pliocene.

The Miocene (or Oligocene?) lavas which cap the hills in so many widely scattered localities throughout the Belt of Interior Plateaus, have been warped to form broad synclinal basins and anticlinal domes. The anticlinal domes have since been removed through denuding agencies. It is found that the present late mature upland (locally a peneplain) truncates or bevels the tilted lavas for great distances. The upland erosion surface in this district may be correlated with one found by the writer during the summer of 1911 in the Franklin Mining district in the Columbia Mountain system. There it truncates the Midway Volcanic group of trachytes and alkalic basalts referred to the Miocene period.

GLACIATION.

The deep pre-Glacial Thompson valley contains a great thickness of fluvio-glacial material now in process of being excavated. Sections of such glacial and interglacial debris exposed by the river and railroad, aid considerably in the determination of the Pleistocene history of the province.

The region of Interior Plateaus was, during the Pleistocene, covered by the Cordilleran ice cap, whose direction of flow here, as shown by striæ, was about S. 35° E. The upland slopes are thickly mantled with morainic drift and erratics left stranded by the retreating ice sheet. On the other hand, the contemporaneous boulder clay deposited in the valleys below, has since been largely removed by the advance of valley glaciers.

With its waning, the Cordilleran continental glacier gave place to alpine, cirque, and valley glaciers. Much englacial and superglacial material was deposited and reworked by water. The older gravels, sands, and stratified clay silts, capped by boulder clay, are referable to this period of alluviation, contemporaneous with the first period of valley glaciation.

The valley ice slowly retreated until the time of the maximum extension of the Keewatin ice sheet on the east, when the second period of valley glaciation in the Cordilleran belt probably took place. This advance of the ice removed much of the older morainic and outwash materials, deeply eroded the valleys, and heaped up lateral and terminal moraines. The high-level esker-like ridges of the valley sides probably represent the work of streams at the borders of the ice. The streams draining the ice front carried down and deposited large quantities of land waste in the form of a deep alluvial fill.

With the melting and recession following the maximum advance of the second period of valley glaciation, large amounts of drift materials were set free. Great thicknesses of silts were then deposited in the tranquil waters of lakes. These lakes were formed on the main valley floors, either dammed by powerful local glaciers entering from the sides, or perhaps locally basined at a time of special subsidence yet greater than that recorded for the late Pleistocene along the Pacific shore. At the mouths of tributary creeks alluvial fans composed of cross-bedded gravels

and sands, were laid down under water and are intercalated in the White Silt formation.

Following the complete withdrawal of the ice from this portion of the Cordillera, the denuded region of former vigorous glaciation would supply but little rock waste to the streams. With the reduction in waste supply and but a moderate reduction in volume, the streams here deeply degraded the earlier accumulations. Degradation was probably further aided by regional uplift which invigorated the streams. Terraces due to the normal lateral swinging of the river, as well as to later minor stages of alluviation and degradation dependent upon climatic change, are present throughout the Thompson valley. An old river bed is found to lie persistently in sharp contact with the White Silt for many miles. It is represented by a coarse gravel with boulders overlapping each other in the direction of flow. It is generally found directly beneath the surface silt and sand of the terrace on the bed-rock side of the valley.

The district between the east end of Kamloops lake and Lytton may be divided into three distinct sections. The eastern section covers Kamloops lake, where the Thompson valley appears to have been glacially deepened to a great extent The result is that the tributary valleys bear hanging relationships to the main valley. There are well developed alluvial fans and cones chiefly of subaqueous origin, at the mouths of the tributary creeks. The main valley itself is comparatively free from glacial outwash material.

The central section extends from the west end of Kamloops lake (26 miles—42 km.) to Thompson Siding (85·3 miles—158k m.). It is characterized by a great depth of Glacial valley-train material, beautifully terraced by the meandering Thompson river. The deeply incised river, however, has only in a few places reached the rock floor of the old pre-Glacial valley.

The western portion of the central section from Toketic to Thompson Siding, owing both to the increased gradient of the river and the narrowness of the valley, contains only narrow terrace lands, and a comparatively small development of the White Silt formation.

The western section, from Thompson Siding to Lytton (9·48 miles—153 km.)—the Thompson Canyon proper—, displays a very mountainous appearance in bold contrast

to the eastern belt. Here the Thompson river has cut completely through the outwash valley-train and has deeply incised itself within the pre-Glacial floor of bed-rock, forming a deep canyon. The canyon bottom contains many huge blocks of rock that have tumbled from above, and are now in process of being broken up and carried downstream by the turbulent river.

STRATIGRAPHY.

The bed-rock geology has chiefly to do with formations of Mesozoic and Tertiary age.

The following is a table of formations in descending order:—

	Approximate thickness (after Dawson).		
Pleistocene and Recent.			Superficial deposits. Glacial till, gravel, sand, clay and silt.
	Feet.	Metres.	
Lower Miocene (?) *	3,000	914	Kamloops Volcanic group; basalt, agglomerate, breccia, trachyte.
	1,000	305	Tranquille beds; fine-grained tuffs.
Eocene (?).......	5,000	1,524	Coldwater group; conglomerate, sandstone, Ashcroft rhyolite porphyry.
Lower Cretaceous.	5,000	1,524	Queen Charlotte Islands formation (?); shales, conglomerate and sandstone.
Jura-Cretaceous..	5,000	1,524	Spence's Bridge Volcanic group; andesitic and liparitic lavas, tuffs, and arkoses.
Upper Jurassic....................			Granitic intrusives; batholiths, stocks, and tongues.
Jurassic-Triassic..	10,000	3,048	Nicola formation; greenstone, impure quartzite, argillite, limestone, agglomerate and tuff.
Carboniferous....	9,500	2,896	Câche Creek formation; cherty quartzite, greenstone and marble.

* Dr. R. A. Daly refers these rocks tentatively to the Oligocene system. See page 149.

The *Câche Creek formation* consists of very badly metamorphosed sedimentary and eruptive material belonging to the Main Pacific geosynclinal. The commonest rock member is a cherty quartzite traversed by veinlets of quartz. Dark massive argillites and contemporaneous eruptives are of more local occurrence. Younger than the above rocks, but in many places intimately interfolded with them, is a limestone formation (*Marble Canyon limestone*) now recrystallized to marble. Large foraminifers known as *Loftusia columbiana* and the diagnostic Carboniferous fossil *Fusulina* are found in the Marble Canyon limestone. Much of the gold found in the placer workings along the Thompson and Fraser rivers may have been derived from the Cache Creek quartz veins. On account of the unfavourable character of the outcrops in the railway section it has here proved impossible to ascertain the full thickness. The estimate of Dawson is noted in the foregoing table.

The *Nicola formation* is well exposed in the Thompson valley and consists of greenstones (altered eruptives of both flow and fragmental type) intercalated with beds of argillite and limestone. Crinoid remains, pelecypods, terebratulas and pectens of several species are found in the calcareous members of the formation. These fossils place the series in the Triassic, grading up into the lower Jurassic. G. M. Dawson estimated that the thickness of the Nicola formation ranges from 10,000 to 15,000 feet. The agglomerates and porphyrites of this formation, by their much more metamorphosed and massive character, are readily distinguished from those of the Tertiary.

The batholiths, stocks and tongues which occur in the district are referred to the upper Jurassic. They are made up of granular intrusive rocks varying from granite to granodiorite and diorite, and are all subalkalic in composition.

During the Lower Cretaceous or late Jurassic, volcanic eruptions broke forth along the east front of the Coast range resulting in the accumulation of over 5,000 feet (1500 m.) of acidic and intermediate lavas and tuffs—the *Spence's Bridge Volcanic group*. This group has heretofore been referred to the Miocene (Lower Volcanic group of Dawson) but recently discovered plant, structural and physiographic evidence place the group in the Lower Cretaceous or late Jurassic.

Like the Coldwater group, the rocks of the Spence's Bridge Volcanic group have been much broken and metamorphosed prior to the outpouring of the Mid-Tertiary lavas.

In the vicinity of Ashcroft, carbonaceous shales, sandstones, and conglomerates occupy a local synclinorium striking nearly north and south. The western portion of the inlier is more steeply inclined and folded than the eastern, where the rocks appear to overlap flatly the Jura-Trias formation. This formation has been referred on lithological grounds to the Lower Cretaceous, and correlated with the *Queen Charlotte Islands formation* on the Pacific Coast.

Another inlier of Lower Cretaceous rocks occurs near the mouth of Botanie creek about two miles (3·2 km.) above Lytton. There, however, the dark shales, grey sandstones and conglomerates are much disturbed and slickensided.

The (probably Eocene) *Coldwater group* consists of continental sediments which include coarse fluviatile conglomerates, sandstones, and shale, with occasional coal. The deposits occupy erosion troughs cut into an older Cretaceous erosion surface. They have been locally upturned and eroded before the eruption of the younger Tertiary volcanics.

The *Kamloops Volcanic* group consists of basalts (both amygdaloidal and vesicular types), agglomerates and breccias, with smaller quantities of younger mica trachytes and various porphyrites. In the railway section the formation has an average thickness of about 2,500 feet (760 m.).

These lavas have a wide distribution through the Belt of Interior Plateaus, and as a rule lie almost horizontal. In places, however, they have been broadly folded into synclinal basins and anticlinal domes. The latter have been eroded away leaving the synclines at present exposed chiefly on the hill tops. Quite locally, but not within the limits of this section, these lavas have been tilted to vertical or nearly vertical positions.

Near the base of the Kamloops volcanics, a considerable thickness of evenly bedded tuffs occur—the *Tranquille beds* of G. M. Dawson. They are, as a rule, pale in colour and contain plant remains, thin coal seams, and occasionally fossil fish of lower Miocene or Oligocene age.

Deposits of Pleistocene age are very plentiful, and consist of Glacial till, gravels, sands, clays and silts.

SUMMARY HISTORY.

There is no record in the Kamloops district of pre-Carboniferous formations, and the area was probably subject to erosion during the early Paleozoic. The Main Pacific Geosyncline was initiated probably in Carboniferous time, and the Câche Creek formations laid down in an eastwardly transgressing sea. Sedimentation was interrupted at times by vulcanism.

The close of the Paleozoic was marked by deformation and a return to continental conditions. Submergence in Triassic time brought a return of marine conditions, with the deposition of argillaceous and siliceous muds and limestones, accompanied by volcanic activity on a grand scale. Vulcanism ceased in Lower Jurassic time and sedimentation continued with the deposition of arenaceous limestones rich in marine fauna.

Orogenic movements in the upper Jurassic were either preceded or followed by intrusions of granitic batholiths, stocks and tongues as well as volcanic activity along the east front of the Coast range (Spence's Bridge Volcanic group).

During the Lower Cretaceous marine conditions were locally restored in geosynclinal downwarps, which received the detritus washed in from the lands, especially from that on the east. Later an emergence took place and these areas seem to have shared in the erosion of the later Cretaceous. Therewith much of the cover of the Coast Range batholith was removed and the Interior Plateau country was brought down nearly to base level.

During the Laramide revolution the thick Mesozoic and older formatioms were greatly uplifted, locally folded and overthrust from west to east. The Coast Range and Columbia Mountain systems were loci of maximum uplift, and may have supported local alpine glaciers.

The Laramide revolution invigorated the drainage and made the rivers deeply entrench themselves within the older Cretaceous erosion surface. The Coldwater group conglomerates, sandstones and shales were then deposited in the erosion troughs and basins.

Local volcanic vents supplied rhyolitic lavas and acidic tuffs which are frequently associated with the early Tertiary formations. During the Oligocene which continued the erosive work of the Eocene, crusta

disturbances took place, uplifting and deforming the early Tertiary formations. This orogenic movement brought about vigorous erosion, and a great volume of the early Tertiary rocks was swept away. Volcanic activity broke forth on a grand scale in the early Miocene,* and great thicknesses of basaltic lavas, agglomerates, breccias and tuffs (Kamloops volcanics) spread over large areas. Crustal warping took place probably in the late Miocene and threw the flat-lying Kamloops volcanics in places into broad anticlinal domes and synclinal basins. Continued erosion in the Pliocene brought the whole belt to a stage of late maturity and local peneplanation. Wide and shallow, trough-like valleys were formed. At the close of the Pliocene or beginning of the Pleistocene, regional uplift took place, and the major streams deeply incised themselves within the uplifted erosion surface. During the Pleistocene, the Cordilleran ice-sheet advanced and retreated, leaving much drift. At least two distinct periods of valley glaciation and alluviation followed the retreat of the ice cap. The disappearance of glacier ice from the valleys increased the eroding activity of the streams which began the dissection of the alluvial gravels, sands and silts. This process of dissection, still active, was probably further aided by regional uplift.

* Dr. R. A. Daly prefers to give weight to the available paleontological evidence which tends to assign the Kamloops and Tranquille formations to the Oligocene. The time of their warping is accordingly to be described as the interval between the late Oligocene and the Pliocene period; and their extensive denudation is ascribed to work performed through practically all of post-Oligocene time.

ANNOTATED GUIDE.

(Savona to Lytton.)

Miles and Kilometres.

25·3 m. 40·7 km. (from Kamloops) **Savona**—Altitude 1,158 ft. (352·9 m.). On Savona mountain which may be seen to the south of the town, occurs a thick section of the Kamloops volcanic group.

In descending order it is approximately as follows:—

Coarse agglomerate on summit................	200 ft.	60·9 m.
Reddish, black and greenish black lavas chiefly vesicular and amygdaloidal................	900 ft.	274·3 m.
Agglomerates, varying to ropy lavas..........	800 ft.	243·8 m.
Grey, black, and red lavas, some vesicular, in places slightly agglomeratic	600 ft.	182·8 m.
Total.....................	2,500 ft.	761·8 m.

Miles and Kilometres.

Three miles west of Savona, Kamloops lake ends at the broad well-terraced delta of the turbulent Deadman river. The growth of the delta has probably raised the level of Kamloops lake.

Thompson river here has been forced to the south and bed-rock side of the valley, and from the railroad may be seen the markedly cross-bedded outwash gravels and silts exposed in the high banks across the river.

The valley of Deadman creek with its glacially steepened walls, may be seen extending for more than ten miles (16 km.) northward, where it merges into the lava-capped upland plateau.

The river west of Deadman creek, follows a tortuous course through the thick alluvial valley-fill. Near the 30th mile-post the river makes a prominent horseshoe bend now cut off to form an island and slough across which the Canadian Northern Railway Company are building their line.

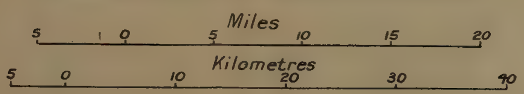
32·1 m.
51·6 km.

Walhachin—Altitude 1,252 ft. (381·6 m.). Walhachin—the centre of an extensive fruit growing district—is situated on the brink of one of the principal fluvio-glacial terraces of the region. The water for irrigation purposes is flumed from Deadman river. The Thompson valley is very wide here, and the river follows a meandering course within it. The result has been a splendid development of broad, gently sloping terraces preserving old meanders and cusps formed by the river at higher levels. Coarse gravel overlying silt, seen from the

Cl,2,3,4.

Geological Survey, Canada.

Route map between **Ducks** and **Lytton**



Miles and Kilometres.

train at many places, represents an old river channel.

A broad belt of Coldwater conglomerate, sandstone, and shale outcrops about one mile (1·6 km.) south of the railroad. These sediments represent an old Eocene river course, later uplifted, eroded and protected from further erosion by remnants of younger lava flows.

The train after leaving the Walhachin terraces, winds around points of Triassic rocks and through alluvial fans built up by tributary creeks, until it reaches the 37th mile-post, where a granitic boss is encountered. The granodiorite extends across the river east of Eight Mile creek, and, a couple of miles north, disappears under the lava cap of the Kamloops volcanic group.

38·4 m. 61·7 km. **Semlin**—Semlin is a railroad siding named from the broad, hanging Semlin valley which joins the main Thompson valley at this point. The Semlin valley is probably an old course of Bonaparte creek.

A short distance west of Semlin station, the railroad cuts through the basal portion of a syncline in the Kamloops volcanics. The syncline, which is a continuation of the Savona mountain remnant, extends northward across the river where it widens out into a broad synclinal belt capping the hill tops. The sequence of the rocks as exposed in the rock cuts, shows lavas of trachytic habit, succeeded above by basaltic lava with columnar jointing. The basalt passes into a dense bluish-black phase with pronounced ball-and-socket jointing. The lava passes upward into grayish tuffs and coarse agglomerates containing fragments of basalt. The upland in this vicinity is a peneplain which truncates the slightly tilted Kamloops volcanics. One mile (1·6 km.) west of Semlin, the railroad emerges from the lava syncline and cuts through great thicknesses of alluvial silts, gravels and till. The clay silt is quite consolidated and stands in vertical cliffs forming in many places weird "hoodoos".

Miles and Kilometres.

In one section there is exposed to view about 150 feet (45·7 m.) of clay silt overlain by bouldery till. The alluvium here is underlain by a granodiorite batholith capped by a continuation of the same series of Kamloops lavas.

The contact between the granodiorite batholith and the Jura-Triassic (Nicola) is near the 43rd mile-post at a narrow part of the valley. The Triassic limestones and intercalated sheets of irruptive rock stand out prominently across the river on the southeast flank of Rattlesnake hill, where the series dips about 45° to the northwest.

The Nicola formation is overlapped from the west by Cretaceous conglomerate, shale, and sandstone—a formation which is encountered first at the mouth of Barnes creek, where the Thompson valley broadens out, preparatory to taking a sharp southward bend in its course. Here the river has been forced back upon the delta of Bonaparte creek by the building out of the Barnes Creek delta. The river has cut deeply northward into the fluvio-glacial silts and gravels west of Rattlesnake hill which stand out in prominent cliffs about 300 feet (91 m.) high. In one place, the stratified clay silts are seen contorted and folded into a synclinal trough which is filled by a younger and more sandy silt. The younger silt was probably carried down and deposited subaqueously by Bonaparte creek in what was then a lake. The silts are believed to be of two distinct periods of alluviation contemporaneous with two periods of valley glaciation. The silts may be traced southwestwardly toward the mouth of Bonaparte creek, where boulder clay is found overlying the cross-bedded gravels, sands and silts of the first period of alluviation. The boulder clay is in turn capped by a coarse river bed deposit with a thin layer of silty soil on the surface of the terrace.

47·2 m. **Ashcroft.**—Altitude 996 ft. (303.5 m.).
75·9km. Ashcroft, "the gateway to the north country", is situated in a wide, level tract of valley land

View showing the characteristic of the topography about Ashcroft.

Miles and Kilometres.

underlain by the readily eroded Cretaceous rocks. The terraced alluvial filling of the valley, where irrigated, is very fertile and produces large crops of potatoes and other vegetables.

From the train one sees terraced outwash Glacial materials skirting the hills of Cretaceous rock which are for the most part capped by Tertiary lavas. The lavas of the mesa-like hills are vesicular and amygdaloidal basalts similar to those at Savona mountain. The main type is a dense, bluish-black basalt showing splendid ball-and-socket, as well as columnar jointing. On the hill seen from the railroad a few miles to the southeast of Ashcroft, this basalt is found capping unconformably a remnant of rhyolitic lava of probably Eocene age.

The topography in this portion of the Thompson valley on account of the semi-arid nature of the climate, approaches the 'bad land' type. The hillsides are dissected by numerous small gullies and ravines as a result of intermittent but violent rainfall.

One half mile south of the 50th mile-post, after passing through the great landslide of October, 1881, a gravel cut shows boulder clay of the first period of valley glaciation, which here underlies the clay silt and gravels deposited during a later alluviation stage of the same period. The railroad cuts through fissile Lower Cretaceous argillites dipping steeply to the west. The rocks at the western border of the Ashcroft Cretaceous are more folded and disturbed than those at the eastern border where they appear to overlap the Jura-Trias rocks. The total thickness of the formation is about 5,000 feet (1524 m.). A coarse basal conglomerate and grit member of the Lower Cretaceous is exposed in the rock cut immediately north of the Black Canyon tunnel.

52·5 m. **Black Canyon**—The Thompson river here
84·4 km. has incised itself, not only through a great thickness of alluvium, but has also cut more

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than 200 feet (60 m.) deep into the bed-rock itself. This bed-rock is black Cretaceous shale and sandstone. On account of the sombre appearance of the rocks, the gorge is known as the Black Canyon.

To the east of the southern portal of the tunnel may be seen typical mud-slide ground. The ground creeps and forms gaping fissures. Where material has broken away to form landslides, steep bluffs remain. These slides and creep of the ground have caused the railroads much trouble and expense.

About two miles (3·2 km.) below the Black Canyon, the Cretaceous conglomerate (largely granitic) grades down, within a few feet, into an angular breccia, which rests unconformably upon the Nicola rocks.

54·6 m.
87·8 km. **Basque**—Opposite Basque siding the Cretaceous ends, and the underlying Paleozoics (Cache Creek formation) appear for the first time. A few miles west of the river may be seen Red hill, named on account of the highly coloured character of the rocks which compose it. The pyritic cherts and sheared rhyolites of the Cache Creek group have been weathered so as to form red outcrops.

A section of Jura-Trias rocks, intruded by tongues from the underlying granodiorite batholith, may be seen a few miles below Basque.

On nearing Spatsum one may see the west flank of a prominent block mountain composed of Jura-Trias limestones dipping and striking conformably with the slope of the hill. The more resistant, massive Jura-Trias rocks, instead of yielding to orogenic stresses by folding and mashing (like the Cretaceous shales and sandstones), yielded rather by bodily overthrust from the west upon a broad underlying granitic batholith. Clinging to the batholith is a rim of chert due to the contact metamorphism at the time of batholithic intrusion.

60·8 m.
97·8 km. **Spatsum**—Altitude 854 feet (260·2 m.). On the opposite side of the river from Spatsum,

Looking up Thompson valley towards Ashcroft; Spatsum Siding in the bottom of the valley.

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gypsum and china clay may be seen in crumbling outcrops of red, yellow and white. The highly coloured decomposed material is almost devoid of vegetation.

The Cache Creek formation crosses the river at Spatsum, and extends southward to Toketic, where black argillites and quartzites of this formation pass under the Spence's Bridge Volcanic group.

Between Spatsum and Toketic there are two places to be seen from the railroad where the Jura-Trias rocks rest unconformably upon the Cache Creek formation. The largest outlier is on the west side of the river and forms a high hill separating the Thompson from Venables valley. Venables creek flows through the southern end of the exposure, and has exposed a very fossiliferous section near 89-Mile Stable on the Cariboo road.

The other outlier, which is in a badly metamorphosed condition, outcrops high up on the east side of the Thompson valley above the great rock slide, at the base of which is nestled an Indian village and church. The Jura-Trias is here in contact with the granodioritic batholith and basal Cache Creek rocks.

There are a series of strike ridges and ravines paralleling the cliff face 1,500 feet (457·2 m.) above the railroad. The Jura-Trias metamorphics dip flatly to the west while the underlying Cache Creek rocks, where observable, dip steeply to the east. The Jura-Trias rocks are crevassed along joint planes nearly at right angles to their bedding.

A couple of miles south of the Rock slide at the mouth of Pukaist creek, the railroad cuts transversely through Cache Creek marble, well exposed across the river in the Canadian Northern Railway tunnels.

67·2 m. **Toketic**—Altitude 810 ft. (246·8 m.). At
108·1 km. Toketic a series of volcanic rocks commence which have been correlated and mapped as the Lower Volcanic group (Miocene?) by G. M. Dawson, but regarding whose age there is

Junction of Nicola and Thompson valleys, near Spence's Bridge.

Miles and Kilometres.

much doubt. The writer regards them as Jura-Cretaceous. These volcanic rocks, which continue as far as Thompson Siding, have, for convenience, been named the Spence's Bridge group. They consist of a badly altered series, chiefly of liparitic and andesitic lavas with interbedded conglomerate, arkose and tuff, the latter containing plant remains of Lower Cretaceous and Upper Jurassic age.

A light yellowish member of the Spence's Bridge Volcanic group is prominently exposed below the mouth of Twaal creek, on the west side of the valley, where the river begins to take a westward course. This is a peculiar acidic lava, with spherulites averaging $\frac{3}{8}$ inch (1 cm.) in diameter and having in places pronounced flow structure. The acidic lavas are intruded by basic dykes, possibly the feeders for the younger Miocene basalts.

One mile above Spence's Bridge the broad glaciated valley of the Nicola joins that of the Thompson.

72·6 m. 116·8 km. **Spence's Bridge**—Altitude 768 ft. (234·0 m.). Spence's Bridge, the junction point for the Nicola Valley railroad, is picturesquely situated in Thompson valley at the base of the precipitous Arthur's Seat mountain.

Arthur's Seat, rising abruptly 5,500 feet (1,676 m.) above sea level, is thought to have been one of a series of volcanic vents which were active along the east front of the Coast range in Jura-Cretaceous time. At the base of Arthur's Seat may be seen silt escarpments, from which a large volume of alluvium broke away on Aug. 13, 1905, damming the Thompson river and causing the destruction of an Indian village across the river. Five Indians were buried alive in the slide, ten were killed and thirteen hurt by the wave which swept up the river.

79·1 m. 127·2 km. **Drynock**—Altitude 752 ft. (229·2 m.). A few miles below Spence's Bridge, the narrowing valley swings southward and maintains a

Miles and Kilometres.

southward course until it reaches Thompson Siding.

The Spence's Bridge Volcanic group is capped a few miles northeast of Drynock by typical basalt of the Kamloops Volcanic group. About 100 feet (30·5 m.) of tuff beds, resembling the Tranquille beds, are present at the contact.

85·3 m. 137·2 km. **Thompson Siding**—Altitude 670 ft. (204.2 m.). At Thompson Siding, the Nicoamen river tumbles over a waterfall to unite with the Thompson which here bends sharply, taking a west course until it reaches the Fraser river at Lytton. The first discovery of gold in British Columbia is said to have been made by an Indian at the mouth of the Nicoamen in 1857. As the train rounds some of the rocky bluffs on the south side of the Thompson Canyon, an occasional glimpse of the snowclad Stein Peak and other Coast Range mountains may be had. The scenery through this canyon portion of the Thompson valley is rugged and mountainous, with huge talus blocks scattered along the channel of the river. There is comparatively little Glacial silt in this portion of the valley. The post-mature upland of the summits grades gradually into the alpine topography of the Coast range. As the train winds through higher upland country, there is a marked increase in the depth of the tributary valleys beneath its surface.

Westward of Thompson, the railroad cuts into highly pyritic quartz schists before entering the eastern border of the Coast Range batholith.

89·7 m. 144·3 km. **Gladwin**—Altitude 745 ft. (227·0 m.). A contact zone between the Coast Range batholith and Paleozoic schistose rocks, the whole traversed by many Tertiary dykes and chonolithic intrusions, is exposed on the steep scarped north wall of the canyon between Gladwin and Lytton. A few miles further west, near the mouth of Botanie creek, is an odd granitic ridge named 'The Crag.' It is cut off sharply to the west by a fault scarp which gives a very irregular outline to the hill. The eastern side

Scarped north wall of Thompson canyon near Gladwin.

Miles and Kilometres.

has a relatively gentle slope, dotted with evergreens.

A small detached area of Cretaceous shale, sandstone and conglomerate, all much disturbed, occurs near the mouth of Botanie creek about two miles (3·2 km.) from Lytton.

From Lytton mountain, which rises about 6,000 feet (1,829 m.) southeasterly above the town, may be seen on a clear day, the Cascade mountains in Washington, and similar rugged alpine summits supporting glaciers and névé fields in the Coast range.

COAST RANGE (Lytton to Vancouver)

BY

CHARLES CAMSELL.

INTRODUCTION.

From Lytton to Vancouver, a distance of 156 miles, (251 km.), the route of the excursion follows the valley of Fraser river. This stream, discovered and explored by Simon Fraser in 1808, is the largest stream in British Columbia whose basin lies entirely within the boundaries of the province. It has a length of 790 miles (1,271 km.) and drains an area of 91,700 square miles (237,686 sq. km.) Rising on the western slope of the Rocky mountains in latitude 53° N., it first flows northward in the great structural valley known as the Rocky Mountain trench until it reaches latitude 54° 15′ where it bends with a wide curve to the west and then to the south. From Fort George its course is almost due south until it reaches Hope, where, in turning westward, it breaks through the mountains bordering the Pacific coast and within 100 miles (161 km.) empties into the Strait of Georgia.

In its course from Lytton to the sea the Fraser traverses two strongly contrasted types of physiographic form, one the rugged mountainous region of the Coast and Cascade Mountain systems, and the other the comparatively level region of the delta. The former of these two physiographic

units comprises a broad mountainous belt lying between the Interior Plateau region and the coast, which has an average width of about 100 miles (161 km.), and a length in Canada of about 900 miles (1,448 km.) It is made up largely of a composite mass of plutonic igneous rocks called the Coast Range batholith, which has been thrust through, and is flanked by, Paleozoic and Mesozoic sediments, blocks of which have been engulfed and are infolded in it.

Looking southwest from Mt. Ferguson, Lillooet district, showing mountains typical of the Coast range.

The delta portion is relatively small and in Canada has an area of over 1,000 square miles (2,592 sq. km.) though it also extends southward into the State of Washington. It is floored by Eocene deposits of estuarine origin which are covered by more recent Glacial and post-Glacial materials.

COLUMNAR SECTIONS.

(By N. L. Bowen).

Eastern part (Lytton to Hope).

Pleistocene and Recent—Till, stream gravels, etc.
Unconformable relation.

Lower Cretaceous —Jackass Mt. series.	*Erosion surface.* Conglomerate, 2,000 ft. (609 m.). Black shale, with marine shells, 500 ft. (152 m.). Green and grey arkoses, with plant remains; 300 ft. (91 m.). *Base not exposed.*

Unconformable relation.

Lower Mesozoic—
Boston Bar group—Thin-bedded grey argillites.
Palæozoic—
Câche Creek group—Cherty argillites, limestone, quartzite, serpentine; thickness and order of succession indeterminate.

WESTERN PART (HOPE TO VANCOUVER).

Quaternary—Till, stream gravels, etc.
Unconformable relation.

Eocene..........	Basaltic and andestic lavas. Conglomerates, grits, shales with plant remains; 3,000 ft. (914 m.).

Unconformable relation.

Lower Cretaceous?—Quartz porphyry flows.
Unconformable relation.

Palæozoic— Agassiz series—	Limestone, 1,000 ft. (304 m.). Black shale, 3,000 to 4,000 ft. (914 to 1,219 m.). Conglomerate, 3,000 to 4,000 ft. (914 to 1,219 m.).

The above sections do not include the granitic rocks, which are apparently of two ages, Jurassic and post-Lower Cretaceous. The older rocks are usually gneissic and sometimes sheared, and include both granodiorites and granites. The younger rocks are always fresher and never gneissic, and usually more acid than the older type. They are dominantly hornblende-rich, in contrast to the older type in which the hornblende is subordinate to a greenish biotite.

THE CANYON OF FRASER RIVER.

Physical Features.

Above Lytton the Fraser flows through the Interior Plateau region, but from that point down to the head of the delta below Hope it is closely hemmed in by the high mountains of the Cascade range on the one side and of the Coast range on the other. These two mountain systems overlap each other for about 100 miles (161 km.) and in

Entrance to Fraser canyon above Yale, with Lady Franklin Rock in the middle of the stream.

the break between the over-lapping edges the river forces a difficult passage until it eventually emerges from them at the head of the delta, to pass around the southern end of the Coast range. This part of Fraser valley is, properly speaking, the canyon of the river though it has become customary when speaking of "Fraser Canyon" to refer to an inner gorge-like constriction 25 miles (40 km.) in length extending from North Bend to Yale.

Throughout its length the main canyon is deep and bordered by mountains which in places reach an altitude of 7,000 feet (2,133 m.) above the sea. The sides of the valley are generally rocky and steep, though the degree of slope varies with the nature of the rocks in which it is cut. For example, it is narrow and very steep-sided where

located in granitic rocks, and broader and more open where the bed rock is the more easily eroded sedimentary rocks. In cross-section it is more or less U-shaped from the effect of valley glaciation.

In the wider portions of the main canyon gravels have accumulated to a considerable depth, but in the more constricted parts deposits of this nature are rare and of very limited extent. The gravels were deposited in the closing stages of the Glacial period, but as a result of later deepening of the stream bed a large part of them has been removed and the remainder left as terraces, marking successive stages in that deepening. As many as a dozen terraces can be counted in the valley at Lytton. Uplift since Glacial times has given the stream such renewed power of erosion as to cause it to cut down not only through the sands and gravels, but even to deepen its bed into the solid rock, leaving rock benches here and there on one side or other of the valley bottom. Benches of this nature are noticeable at Spuzzum and near Saddle Rock.

The grade of the stream varies from about 4 feet to the mile (·76 m. per km.) in the portions above and below the inner canyon to 8 feet to the mile (1·52 m. per km.) in the inner canyon itself.

Virtually all the streams tributary to the Fraser river along the main canyon, and particularly those of small volume, enter through hanging valleys. The development of the hanging valleys is in the main due to glaciation though in one or two instances the hanging valley effect is heightened by post-Glacial deepening of the main stream itself.

GEOLOGY.

Stratified rocks of Carboniferous age (Cache Creek) consisting of cherty quartzites, argillites, limestones, serpentine and volcanic flows are the oldest rocks in the main canyon. These rocks have been greatly disturbed and now dip at high angles, striking diagonally across the river. They have been in part intruded by granitic rocks and in part covered by later stratified rocks so that they now have a small areal extent.

Plutonic igneous rocks, mainly granodiorite, are exposed throughout a great part of the main canyon, especially in the gorge below North Bend. They belong to the great

Coast Range batholith, and while the major portion of them is of Jurassic age, some are believed from their structure, to be post-Lower Cretaceous. These rocks, especially the older ones, show shearing and faulting and have two well developed lines of fracture, namely N. 15°W. and N. 20° E., which to a considerable extent influence the direction of the stream. From Yale to Hope they are traversed by a wide shear zone striking north and south, and along this the stream has directed its course.

Lower Cretaceous rocks occupy the valley of the river below Lytton, and appear as erosion remnants near Hope; they consist of conglomerate, slate and sandstone, which contain a few marine fossils.

No deposits of Tertiary age occur in the main canyon, though in the delta immediately below there is a great thickness of Eocene beds, and in the region above the canyon are Oligocene sediments, associated with volcanic flows.

Glacial deposits of till, sand, and gravel fill the lower parts of the valley wherever they have found space for lodgment. They have been carved into terraces by the stream, and more recent deposits of gravel have been formed. These recent gravel deposits are the high-grade gold-bearing placers which caused a great influx of placer miners to the region in 1858 and the years following, and from which many millions of dollars worth of gold have since been won.

ORIGIN AND HISTORY OF FRASER CANYON.

The origin and history of Fraser canyon are by no means clear. In attempting to work them out, one need not go farther back in geologic time than the revolution following the deposition of the Lower Cretaceous rocks. It is clear from the geology of the region that during Lower Cretaceous times no stream could have existed along the present course of the river, for the region of the canyon was at that time a geosynclinal basin occupied by an arm of the sea. This region was however elevated into a land area in later Cretaceous times. The development of drainage systems must then have begun in this region, and among them very probably that of the Fraser river, for reasons which follow.

It is generally conceded by all who have worked in the central part of British Columbia that the development of the plateau features of the interior were initiated by long continued erosion acting throughout Eocene times. The enormous amount of material eroded during this period must have been carried away by streams and deposited elsewhere, and the only considerable development of Eocene beds in that part of the continent is found in the delta of the Fraser river and in the neighbouring parts of the State of Washington. The structure of these beds indicates clearly that they were laid down as delta deposits in an estuary of the sea; while in shape they have here a deltoid arrangement with the apex of the delta pointing up Fraser valley towards the lower end of the canyon. The shape of these Eocene deposits suggests that the stream, which carried the material of which they are composed, had its outlet at or near the lower end of the present canyon and it is probable that the course of that stream was along the present course of the river at least as far as the Interior Plateau region. This evidence, however weak, is the first that we have of any stream existing along the present course of the Fraser river.

However, G. M. Dawson, who has studied the history of Fraser river above the canyon, reached the conclusion that the course of the river, as it exists to-day in the plateau region, was only defined since the deposition of certain flat-lying Miocene or Oligocene beds, through which the river now cuts. Those beds however could have been deposited in a lake or an expansion of the river where still-water conditions prevailed along its course.

The selection of the course of the stream along its present lines has been governed largely by the structure of the rocks through which it flows. For example, for 8 miles (12·8 km.) below Lytton it flows in a band of Lower Cretaceous rocks which have been down faulted against the granite rocks and beyond this it follows closely the contact of these Lower Cretaceous rocks with the underlying Palæozoic formation as far as North Bend. Also, in the gorge below this, though the trend of the valley is in the main due south, in detail the course of the stream has two well defined directions which correspond to two lines of weakness in the granite rocks in which it is cut. These two lines of weakness strike N. 20° E. and N. 15° W. Below the gorge also the valley is carved out along structural

lines in the bed-rock formation. The canyon of Fraser river is therefore a subsequent valley and is developed as a result of rock structure. The composition of the rocks, however, has had a marked determining effect on the shape of the valley, for it is wide in the soft sedimentary rocks and sheared granitic rocks but is narrow in the massive igneous rocks.

Fraser river, looking down from Yale; valley here widened out on greatly sheared granite of the Coast Range batholith.

If the course of Fraser canyon was defined in Eocene times it is very likely that it has followed the same channel down to the present, for the Eocene beds of the delta show that there was no great structural disturbance, even in Miocene times, in that part of the valley, such as might cause the stream to shift its course. The absence of Miocene and Pliocene delta deposits does not necessarily disprove the idea that the stream persisted along that course throughout those periods, because deposits of those ages were probably carried farther out to a point now covered by the sea before they came to rest, or if deposited sooner have since been eroded away. It is more than likely, therefore, that, having defined its course in Eocene times, the Fraser has persisted along that course down to the present.

Long-continued erosion, acting throughout the early and middle Tertiary, must have produced, by the beginning

of the Pliocene period, a fairly mature valley with wide, flaring sides, and a floor several hundred feet above the present stream bed. A well defined topographic break on the slope of spurs projecting into the valley 1,500 (457 m.) to 2,000 feet (784 m.) above the present stream bed may mark the old valley slope. When the Pliocene uplift took place, elevating the Cascade range and the adjacent part of the Coast range, the stream was revived and the deepening of the gorge was begun.

At the close of the Pliocene the canyon was problably sharper than the present canyon with, however, the same variations in character due to the relative resistance of the rock formations Glaciation subsequently widened the bottom of the valley to its present shape.

At the close of the Glacial period the land was depressed below its present level and unconsolidated deposits of sand and gravel were laid down in the bottom of the valley to a depth of several hundred feet.

Elevation of the land in relation to the sea has since taken place, and the erosive power of the stream has again been revived. It has consequently cut down through the Glacial deposits. leaving a series of terraces at different levels to mark successive stages in the deepening of the valley. In the gorge, deepening has progressed through these Glacial deposits and into the solid rocks below to a depth of about 100 feet (30·5 m), leaving remnants of the old valley floor as rock benches on one side or the other of the stream. The amount of uplift appears to have been greater in the interior than on the coast.

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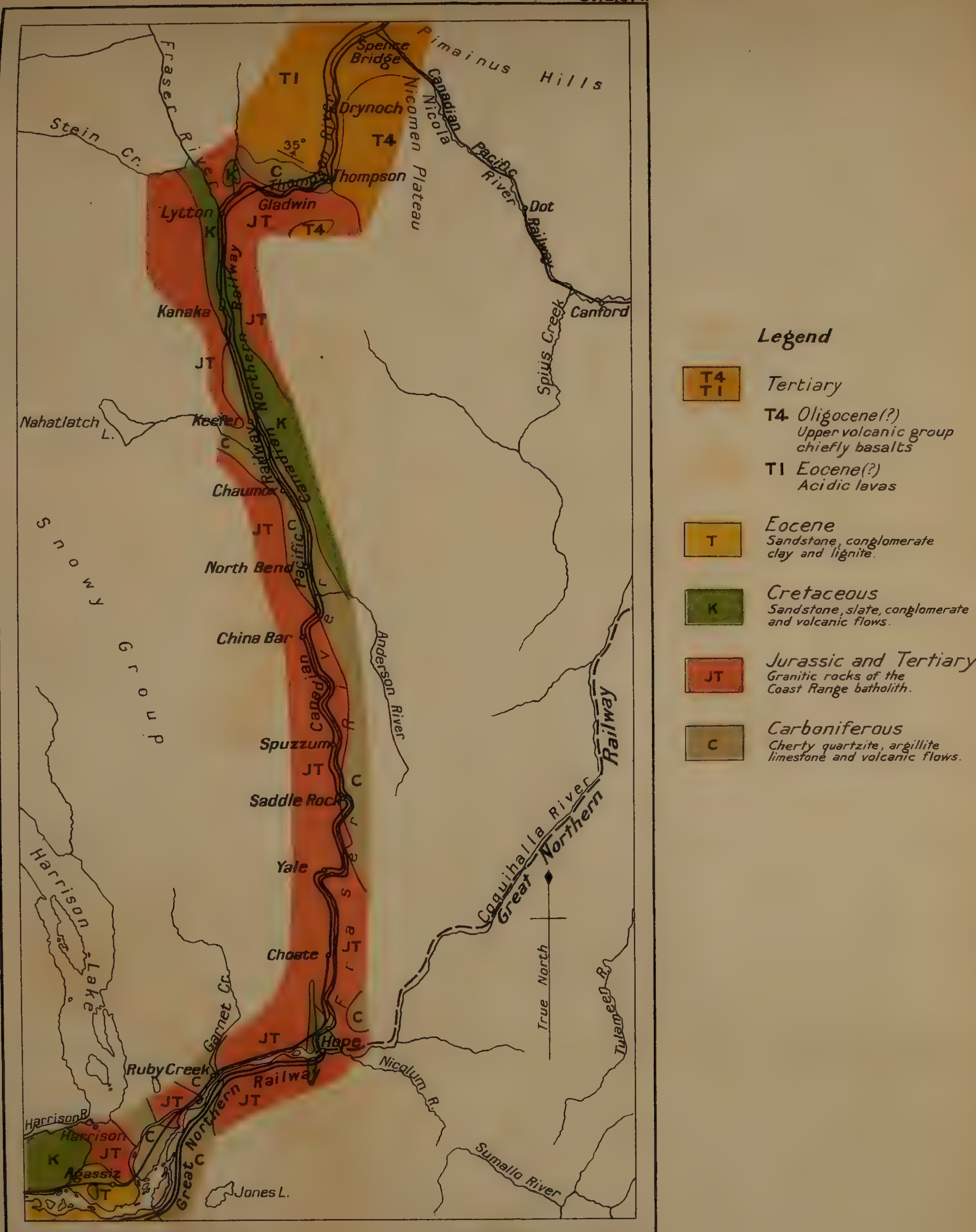


Geological Survey, Canada.

Route map between **Lytton** and **Agassiz**

Miles
10 5 0 10 20

Kilometres
10 0 10 20 30

ANNOTATED GUIDE.

(Lytton to Agassiz).

Miles and Kilometres. (From Lytton.)

0 m. 0 km. **Lytton**—Alt. 687 ft. (209.3m.). The Thompson river empties into the Fraser at the town of Lytton, and from this point westward to the Pacific coast the railway follows the course of the Fraser river, which for about 80 miles (129 km.) cuts a deep canyon-like valley through the mountains bordering the coast, and afterwards flows for 70 miles (112 km.) through a delta of its own construction to the sea. In the neighbourhood of Lytton a series of well developed river terraces can be seen in the lower part of the valley. These terraces mark successive stages in the deepening of the valley since the deposition of drift material in the closing stages of the Glacial period.

For eight miles (12·8 km.) below Lytton the rocks in the immediate neighbourhood of the railway are of Lower Cretaceous age striking nearly parallel to the river and dipping at low angles. To the west these rocks are in contact with granitic rocks against which they are down faulted. The attitude and structure of the Cretaceous rocks is well shown at the bridge near Cisco, where the railway crosses to the west side of the river. There also a tunnel cuts through the fossiliferous black shale of this series.

8 m. 12·8 km. **Kanaka**—Alt. 623 ft. (189.8 m.). At Kanaka a belt of Palæozoic rocks appears to the west of the river and for a few miles southward the river follows the line of contact between these rocks and the Lower Cretaceous. About three miles (3·2 km.) below Kanaka, Jackass Mountain, which is made up of massive conglomerates overlying black shale, rises as a long steep bluff from the water edge. In the course of building a line along the face of the bluff the Canadian Northern railway company has been seriously handicapped by rock slides

Miles and Kilometres.

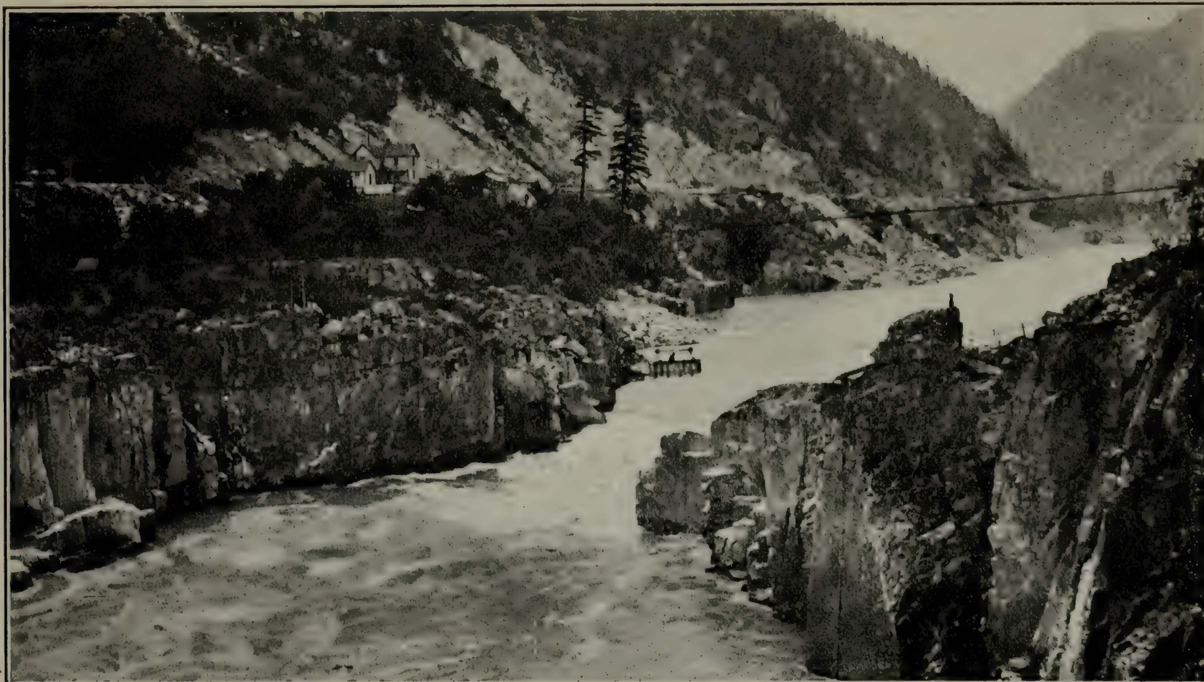
which have left great gashes in the side of the mountain.

14 m. 22·5 km. **Keefers**—Alt. 555 ft. (169m.). Near Keefers and below it the Palæozoic rocks occupy both sides of the valley and continue to a point three miles (4·8 km.) below North Bend.

27 m. 43·4 km. **North Bend**—Alt. 487 ft. (148 m.). About two miles (3·2 km.) above North Bend the banded grey argillites of the Boston Bar series appear. These rocks have yielded Dr. Bowen a single, definitely Mesozoic fossil. Since they are cut by the late Jurassic granites, they are either Jurassic or Triassic in age. Much placer gold mining was at one time carried on in this part of Fraser valley, and the evidence of such work is still to be seen in many places, particularly at Boston Bar, a mile below North Bend. Three miles (4·8 km.) below North Bend, the Palæozoic sedimentary rocks are intruded by granitic rocks of the Coast Range batholith. The contact however is not a clean-cut line of separation between the two formations, but is rather a wide zone marked on the side of the intruded rocks by numerous apophyses of the igneous rocks in the sedimentary, and on the side of the batholith by inclusions of the Carboniferous rocks in the batholith. The zone of apophyses is well shown in the railway cuts on the west side of the river.

32 m. 51·5 km. **China Bar**—Alt 466 ft. (142 m.). Turning a sharp bend in the course of the valley four miles (6·4 km.) below North Bend, the railway enters what is popularly known as "Fraser Canyon," a narrow rock-walled gorge in the main canyon, cut into the massive granitic rocks of the Coast Range batholith, which here form the axis of both the Coast and Cascade Mountain systems. The gorge has a length of 25 miles, (40·2 km) and though a serious barrier both to water and land transportation, it forms the only natural route of travel between the coast and the interior of British Columbia.

Although referred to as a canyon for the whole 25 miles (40·2 km.) of its length it is



Constriction of Fraser river at Hell's Gate near China Bar. The ledges are composed of jointed granodiorite.

Miles and Kilometres.

not uniformly canyon-like throughout, but is rather a succession of narrow gate-like constrictions connecting somewhat broader expansions of the river. Through these narrow passages the water rushes with greatly increased velocity and tremendous force, swirling and eddying from wall to wall and forming such a confusion of currents as to make the navigation of these gaps exceedingly hazardous in low water and absolutely impossible in a high stage. Hell's Gate, Black Canyon, and Chaquama Canyon are among the most remarkable of these constrictions, the first and last mentioned each having a width of about 200 feet (61 m.).

For almost its entire length the gorge is cut into granitic rocks of medium acid composition, the predominating type of which is a gneissic granodiorite. Though the larger proportion of these rocks is of Jurassic age, some are considerably younger and from their structure and lack of metamorphism are probably of early Tertiary age. These younger rocks are easily identified even from a distance by their well developed and regular places of jointing; because of this characteristic they have been used to a large extent by the railway companies in the lining of tunnels and in other types of masonry.

Skuzzy creek, a roaring torrent, plunges out of a hanging valley into the Fraser river at China Bar near the upper end of the gorge. On the opposite side of the river in a steep bluff can be seen a network of light-coloured aplite dykes traversing the granodiorite. The stream here runs in an almost direct line southward, gradually becoming narrower until two miles (3·2 km.) below, it rushes through Hell's Gate between vertical walls of massive jointed granodiorite.

43 m. 69·2 km **Spuzzum**—Alt. 395 ft. (118·8 m.). Beyond Hell's Gate the railway enters a succession of tunnels cut through projecting bluffs of rocks in a moderately wide part of the valley, on

Miles and Kilometres.

passing which the valley again narrows quickly to the constriction called "Black Canyon". Here, as elsewhere throughout the length of the gorge the line of the Canadian Northern railway can be seen under construction on the opposite side of the river. A number of bridges slung on wire cables and used by the builders of that line span the river in several places. The remains of the old Alexandra Bridge, where the historic Cariboo road crossed the river, can still be seen two miles (3·2 km.) above Spuzzum. The Indian village of Spuzzum, a mile below the station of the same name, is built on a delta fan of Spuzzum creek.

Saddle Rock—The valley widens again at Saddle Rock where it passes over for at short distance from the batholith into tilted Carboniferous rocks. At Saddle Rock, and a "Chaquama Canyon" 2 miles (3·2 km.) below, where the stream is only 200 feet (60·9 m.) in width for a distance of 1,000 feet (304·8 m.), rock benches have been developed on the west side of the valley as a result of post-Glacial deepening. A number of shorter constrictions follow in the next 4 miles (6·4 km.). One mile and a half (2·4 km.) before reaching Yale the valley seems closed altogether and no outlet is visible. The stream, however, takes a sharp bend to the west, and after flowing around Lady Franklin Rock, it suddenly emerge into a broader open valley and the gorge is left behind.

54 m.
86·9 km.

Yale—Alt. 215 feet (65·5 m.). Yale is one of the oldest places on the Fraser river, having been established by the Hudson's Bay Company as a trading post in 1856, and was a place of considerable importance in the early days of the gold excitement in Cariboo. From this point down to Hope, the valley of the river lies in a wide shear-zone in an acid granite, forming a phase of the Coast Range batholith; in consequence of this its width is greater than that which obtains in the gorge. The white cliffs

Miles and Kilometres.

seen in the west side of the valley near Emory creek show the effect of this shearing.

Choate—

65 m. 104·7 km. **Hope**—Alt. 209 feet (63·6 m.). Looking directly down the valley from Yale, a high mountain fills the view and at the base of this is the town of Hope, from which point the old Dewdney pack-trail, once the main highway to the interior of the Province, runs eastward over the mountain ranges. The Paleozoic rocks are again in evidence at Hope, and on them rest patches of Cretaceous conglomerate, remnants of a larger synclinal basin which once stretched southward, across the International Boundary line.

75 m. 120·7 km. **Ruby Creek**—Alt. 96 feet (29·3 m.). Half a mile beyond Hope, a younger massive hornblende granite appears, and from here down to Agassiz at the head of the delta of the Fraser, this is the prevailing rock, though occasionally as at Ruby creek one sees exposures of the Carboniferous rocks.

"The relationship of the later hornblende granites to these sediments is particularly well shown. Where the unroofing of the granite is rather far advanced, it appears as fairly regular masses elongated in a northwesterly direction and therefore cutting across the strike of the sedimentary rocks. Beds are truncated sharply, but appear again on their strike, across a width of two or three miles of granite, quite as if no interruption had taken place. Where unroofing is still imperfect, granite occupies the lower slopes of the hills and is capped by the bedded rocks. These receive numerous dykes and sills from the granite beneath, but preserve their strike and dip entirely intact. In short, there is shown most convincing evidence of replacement, rather than displacement, of the sediments by the invading magma." (N. L. Bowen.)

Although the trend of the valley is now directly across the strike of the mountain axes, the

Miles and Kilometres. width increases gradually, the mountains, particularly on the southeast side, retreating farther and farther back. The grade of the river also changes and is reduced from eight feet to the mile (1·52 m. per km.), which it held in the gorge, to about three feet to the mile (·57 m. per km.). The vegetation, too, becomes typical of the Pacific coast and shows the effect of a moist, warm climate on a rich soil.

86 m. 138·4 km. **Agassiz**—Alt. 54 ft. (16·5 m.). Agassiz is virtually at the head of the Fraser delta. Five miles (8 km.) to the north, at the southern end of Harrison lake, is the hot spring known as St. Alice's well. The waters, which contain a large percentage of sodium and some potassium sulphate, rise with a temperature of 150° F. out of the crevices in Cretaceous rocks near the contact of a later hornblende granite. The springs probably represent the last traces of volcanic forces which were once active in this part of the Coast and Cascade mountains and of which Mt. Baker, to the south, is such a striking witness.

FRASER DELTA.

Topography.

The delta of the Fraser river is compound in structure and was built up at different times, beginning with the Eocene. Its construction was continued at the close of the Glacial period and is being carried on at the present time. The region embraced within this compound delta extends from Agassiz westward to the Pacific coast and runs southward across the International Boundary line. To the east it abuts against the Cascade range, and its northern boundary is the Coast range, while its southern limit is in the State of Washington.

The topography of the delta is in the main low and fairly level, with elevations ranging from sea level to about 400 feet (122 m.) above it. However, here and there in the upper part an isolated hill stands above the general level, reaching an altitude of about 1,000 feet (304·8 m.) above the sea. Sumas and Chilliwack mountains are typical examples of the higher eminences.

Geology.

The oldest exposed rocks are the granitic rocks of the Coast Range batholith, which border and underlie the delta on the north.

Remnants of once more extensive Lower Cretaceous rocks form some of the hills in the upper part of the delta, and around these the more recent deposits were laid down.

Virtually the whole of the delta, with the exception of those parts covered by the Cretaceous remnants, is believed to be floored by stratified rocks of Eocene age, which are referred to in the literature as the Puget group. They consist of little disturbed beds of conglomerate, sandstone and shale which were laid down by the ancient Fraser river in an estuary of the sea. They have a thickness of about 3,000 feet in Canada, but are much thicker in the State of Washington. They contain a variety of plant remains and some small seams of lignite.

The Eocene beds suffered erosion throughout the remainder of Tertiary times, but towards the close of the Glacial period were overlaid throughout by sands, gravel and till. These deposits now constitute broad, flat-topped plateaus about 400 feet (122 m.) high, which were once continuous as the late Glacial delta of the river. They have, however, since been dissected by the present stream, as a result of post-Glacial elevation. This process of dissection is related to the strong terracing of the Glacial deposits in the upper part of the Fraser river.

A modern delta is at present being formed by the river and pushed seaward into the Gulf of Georgia.

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ANNOTATED GUIDE.

(Agassiz to Vancouver).

Miles and Kilometres.

95 m. 152·8 km. **Harrison Mills**—Alt. 40 ft. (12·2 m.). From Agassiz to the coast the railway runs through the agricultural country of the delta, which is everywhere covered with deep alluvium and, in consequence, rock exposures are rare. The whole delta is believed to be floored by deposits of Eocene age, which are covered by Glacial and post-Glacial deposits of the same character. Knobs of granitic rocks and Lower Cretaceous quartz porphyries project through the more recent deposits.

Harrison river is crossed at Harrison Mills, and beyond, the railway curves around and behind an outlying knob of these granitic rocks.

Hatzic—Alt. 30 ft. (9·14 m.).

114 m. 183·4 km. **Mission**—Alt. 21 ft. (6·4 m.).

Silverdale.

As far down as the sea coast the railway skirts the southern base of the Coast Range mountains, which are composed of the granitic rocks of the Coast Range batholith. Occasionally cuts are made into projecting points, which show their character. At Silverdale a part of the old floor on which the Eocene delta deposits were laid down is exposed. This floor is presumably part of the Coast Range batholith, and its deeply weathered character indicates that it was long exposed to the action of weathering before the deposition of the Eocene deposits. The irregularity of that old floor, and the attitude of the Eocene deposits in relation to the adjacent mountains, suggest also that during the deposition of those deposits the neighbouring region of the Coast range was then, as now, one of considerable relief.

Ruskin—

130 m. 209·2 km. **Haney**—Alt. 19 ft. (5·8 m.).

Miles and Kilometres.

132 m. 212·4 km. **Hammond**—Alt. 21 ft. (6·4 m.). At Ruskin the Fraser is joined by Stave river. Six miles (9·6 km.) up the latter valley is a hydro-electric plant, generating at present 26,000 horse-power. Exposures of post-Glacial stream deposits are now frequently seen in the railway cuts. These stand at a level of 40 feet (12·2 m.) or more above the present level of the stream.

140 m. 225·3 km. **Westminster Junction**—Alt. 28 ft. (8·5 m.).

144 m. 231·7 km. **Port Moody**—Alt. 13 ft. (3·9 m.). Crossing Pitt river near Westminster Junction, the railway leaves the Fraser river and passes over a low divide to the head of Burrard inlet, the southern shore of which it then follows to Vancouver.

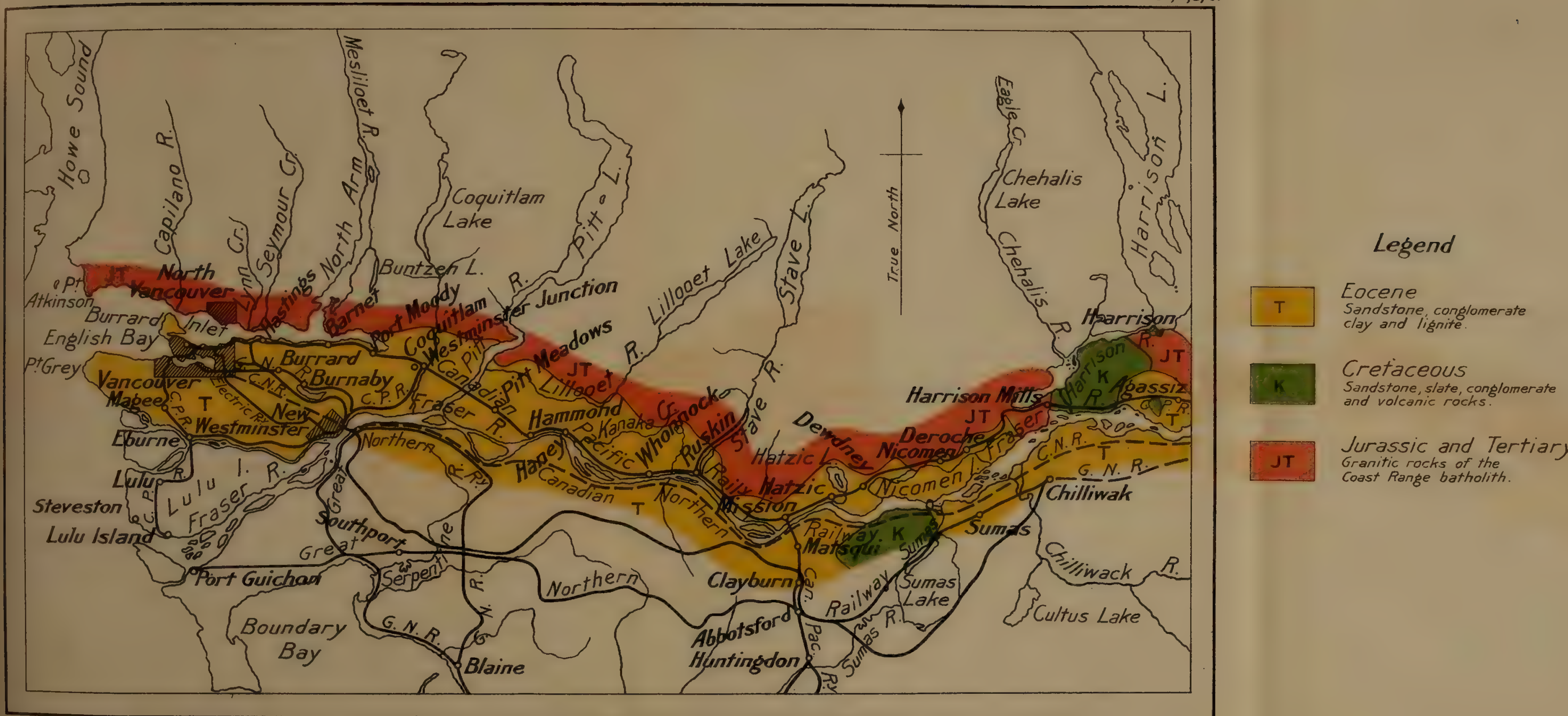
147 m. 236·5 km. **Barnet**—

Hastings—

156 m. 251 km. **Vancouver**—

In the cliffs along the shore of Burrard inlet good exposures of the Eocene beds may be seen. These deposits have been proved by borings to rest directly on the rocks of the Coast Range batholith, and to have a thickness under the City of Vancouver of several hundred feet. They consist of sandstone, conglomerate and clay. They have the structure of delta deposits and were probably deposited in the delta of the ancient Fraser river. They are well exposed in the sea-cliffs at Stanley Park, where also they are intruded by dykes of porphyrite.

C1,2,3,4.



Geological Survey, Canada.

Route map between **Agassiz** and **Vancouver**

Miles
10 5 0 10 20

Kilometres
10 5 0 10 20 30

GUIDE BOOK No. 8

Transcontinental Excursion C 1

Toronto to Victoria and return via Canadian Pacific and Canadian Northern Railways

PART III

ISSUED BY THE GEOLOGICAL SURVEY

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1913

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VANCOUVER ISLAND.

BY

CHARLES H. CLAPP.

INTRODUCTION.

The Vancouver Island excursions afford an opportunity to study the geology of a readily accessible area which is fairly representative of the whole Pacific Coast region of North America, and to examine the most important coal field of that region. Features of wide geological interest to be seen, are:—(1) Ancient volcanism, including flows and fragmental rocks, denuded volcanoes, fossiliferous tuffs, columnar jointing, and pillow structure. (2) Dynamic and contact metamorphism of basic volcanics and associated limestones producing marbles, amphibolites, and garnet-diopside-epidote rocks. (3) Batholithic and dyke intrusives, illustrating contact shatter-breccias, differentiation, sequence of the different phases of igneous activity, and origin of primary gneisses. (4) Sedimentation, illustrating unconformity, rapid lateral and vertical gradation, calcarenites, sandstone dykes, and coal. (5) Glaciation, grooves, striations, roches moutonnées, glacial and interglacial deposits, such as deltas with terraces and kettles. (6) Physiographic features, peneplain and monadnocks, glacial lakes and fiords, and various types of shore-lines. (7) Economic geology, contact deposits, coal and other non-metallic materials.

GENERAL GEOLOGY AND PHYSIOGRAPHY.

Vancouver island (**4**) is one of the border ranges of North America and is separated from the mainland by the submerged northern portion of the great marginal depression of North America, known as the Pacific Coast downfold (**17**). This depression is flanked on either side by great mountain ranges; in British Columbia by the Coast range to the east and the ranges of Vancouver island and Queen Charlotte islands to the west. The Vancouver range, which virtually constitutes Vancouver

island, trends N. 55° W. The entire island is 290 miles (470 km.) long and 50 to 80 miles (80 to 130 km.) wide, the total area being about 14,000 square miles (36,000 sq. km.). It is, as stated, separated from the Coast range of the mainland by the submerged northern end of the Pacific Coast downfold, which is occupied from south to north by Haro, Georgia, Johnstone, and Broughton straits and Queen Charlotte sound. It is separated from the mainland to the south, that is from the Olympic mountains of Washington, by a smaller transverse downfold, striking about N. 70° W., now occupied by the Strait of Juan de Fuca.

Vancouver island is composed of deformed metamorphic, volcanic and sedimentary rocks, intruded and replaced by numerous irregular bodies of granitic rocks, and fringed along both coasts with fragmental sediments, which rest unconformably upon the metamorphic and granitic rocks. The metamorphic rocks are largely of lower Mesozoic age, presumably upper Triassic and lower Jurassic, but they may include some Palæozoic members. Apparently the oldest rocks, considered provisionally as of late Palæozoic (Cariboniferous) age, are a series of slates and quartzose schists, with some fragmental volcanic members. This series extends across the southern end of the island and is called the Leech river formation.

The lower Mesozoic rocks comprise the larger part of Vancouver island, and constitute the Vancouver group. They consist chiefly of metamorphosed basic volcanics, principally meta-andesites, the Vancouver volcanics. Certain schistose and more salic volcanic rocks are apparently interbedded with the Leech river formation, but the typical meta-andesites, although separated from the Leech river formation largely by faults, are apparently younger and unconformable. Associated with the Vancouver meta-andesites and occurring chiefly in small intercalated lentils, is a formation of limestones called the Sutton formation. Besides the limestones, there is associated with the meta-volcanics a series, of stratified slaty and cherty rocks, the Sicker series, composed partly of volcanic material. These rocks and their associated volcanics have been greatly metamorphosed and converted into schists.

All of the above mentioned rocks are intruded and partly replaced by batholithic and dyke (minor intrusive) rocks.

The batholithic rocks are chiefly granodiorite with marginal facies of diorite, but in the southeastern part of the island there is a large batholith of gabbro-diorite and quartz-diorite gneisses. All of the batholithic rocks are closely related and appear to have been irrupted during the same general period of intrusion. Nevertheless they may be subdivided into four types that were irrupted in a definite sequence, apparently as follows:—Wark gabbro-diorite gneiss, Colquitz quartz-diorite gneiss, Beale diorite, and Saanich granodiorite. It is probable that all the 'minor intrusives' also, salic and femic porphyrites, were irrupted during the same general period.

Unconformable upon an erosion surface of the metamorphic and granitic rocks, and confined for the greater part to the east coast of the island, is a thick conformable series of fragmental sediments, the Nanaimo series, largely of upper Cretaceous age. It consists of conglomerates, sandstones, and shales, with some coal. In general, it has been deformed, into broad open folds with a northwest-southeast strike, and a general northeast dip, but in places it has been closely folded, overturned to the southwest and broken by reversed and overthrust faults.

The deformation of the Nanaimo series probably occurred in post-Eocene times. Previous to it, during upper-Eocene times, a thick formation of volcanic rocks, the Metchosin volcanics which are chiefly basalts, was accumulated in the southern part of the island. These volcanics were involved in the post-Eocene deformation, and at the same time were intruded by stocks of gabbro, the Sooke gabbro, which ranges from a femic to a salic gabbro and even to true anorthosite.

In later Tertiary time during the erosion cycle initiated by the post-Eocene deformation, the Vancouver range was reduced to a subdued surface, which in its southern part was a peneplain with a few monadnocks remaining a few hundred feet above the general level. In its central part, however, the surface was one of considerable relief, with larger and higher monadnocks and small ranges of mountains. During this cycle a large part of the detritus was deposited off the southern and western coasts of the island against a submerged mountainous slope, and formed a coastal plain, composed largely of coarse conglomerates and sandstones, the Sooke and Carmanah formations. The subdued and peneplained Tertiary erosion surface and the coastal plain

Southern part of Vancouver range, showing uplifted and dissected Tertiary peneplain, with few and relatively low monadnocks. Southern part of Malahat district, looking northwest from Mt, Shepherd.

deposits were subsequently uplifted, presumably during Pliocene times, and were then dissected during a pre-Glacial cycle, initiated by the uplift. Over the larger part of the island, the dissection, which was presumably accomplished by revived, large, transverse streams with subsequent tributaries, reached a stage of maturity, and the Tertiary peneplain and subdued surface is still preserved in the wide, relatively smooth interstream areas. The present elevation of the uplifted Tertiary peneplain is less than 1,500 feet (450. m.) near the southern coast, but increases rapidly to the northwest, so that in the central part of the island, the elevation of the uplifted subdued surface is about 4,000 feet (1200 m.), while the old residuals are now since uplift, 5000 to 7,000 feet (1,500 to 2,100 m.) above sea level, a few peaks being even higher.

In the southeastern portion of the island, although the region is largely underlain by crystalline rocks of the same character as the rest of the island, the dissection was carried to a further stage, that of late maturity to old age, so that the Tertiary peneplain was entirely destroyed and another subdued surface was developed several hundred feet lower, now averaging about 100 feet (30 m.) above sea level, but surmounted by numerous relatively small monadnocks. The sedimentary rocks along the coasts, the Nanaimo series along the east coast and the Sooke and Carmanah formations along the west coast, being less resistant than the crystalline rocks which form the larger part of the island, were also, reduced during the pre-Glacial cycle to a lowland, exposing the mountainous slope against which the Sooke and Carmanah formations were deposited. These latter formations were, after further uplift, also retrograded so that now mere remnants of the former Tertiary coastal plain exist, fringing the southern and western coast of the island. It seems as if at some time following the mature dissection of the uplifted Tertiary peneplain and the development of the lowlands, the southeastern portion of the island was depressed in part below sea-level, drowning the valleys, but leaving the higher elevations as islands and promontories, and thus forming the irregular drowned coast characteristic of that part of the island.

In Pleistocene times, Vancouver island was apparently smothered by a thick ice-cap, which smoothed and rounded all the mountains under 4,000 or 5,000 feet (1,200 to 1,500 m.) high, while the pre-Glacial valley heads in the higher

mountains were excavated by local glaciers, so that these high mountains now have characteristic serrated summits. Valley glaciers occupied and scoured out the larger valleys, converting some of them, chiefly the transverse valleys flowing southwestward from the main range to the Pacific, into fiords, and deepening some of the interior valleys into large lake basins. The valley glaciers flowing eastward from the east slope of the Vancouver range joined with

Block diagram, illustrating topography of southern Vancouver island.

the larger and more numerous glaciers flowing westward from the range of the mainland, and formed an extensive piedmont glacier which occupied the downfold between the Vancouver range and the ranges of the mainland. The southward flowing portion of this piedmont glacier, [8] called the Strait of Georgia glacier, overrode the lowland developed by the pre-Glacial cycle in southeastern Vancouver island and sub-maturely glaciated it. On the retreat of the earlier and larger glaciers of the Admiralty epoch, the land stood at least 200 feet (60 m.) lower than at present, and during an inter-glacial epoch, the Puyallup, the lowlands developed by the pre-Glacial cycle were covered by marine and delta deposits composed largely of glacial detritus, the Maywood clays and Cordova sands and gravels. During a later and less intense epoch of glacial advance, the Vashon, the inter-glacial deposits were

partially eroded by the smaller glaciers. The apparently rapid retreat of the Vashon glaciers left the inter-glacial deposits partly covered by a younger drift and by large delta deposits, the Colwood sands and gravels, built at the front of the larger retreating valley glaciers.

A recent uplift of some 250 feet (75 m.) has caused a partial recovery from the former depression, which, as mentioned above, resulted in the drowned coast of south-eastern Vancouver island, and has initiated the present marine cycle. During this cycle the uplifted Pleistocene deposits have been retrograded to form steep cliffs some 250 feet (75 m.) high, while the coast, where composed of the crystalline rocks, presents the initial irregularities of the drowned glaciated surface. Inland the uplifted Pleistocene deposits have been terraced by the streams revived by the uplift, and the larger of the revived streams have cut narrow canyons, from 100 to 300 feet (30 to 90 m.) deep, in the hard rock.

ANNOTATED GUIDE.

VANCOUVER TO VICTORIA.

(Excursion C 1, and C 2, Section 1.)

Miles and Kilometres.

0 m.
0 km.

Vancouver—Leaving Vancouver the steamer sails westward through the narrow pass, called the First Narrows, at the entrance of Vancouver harbour, into the Strait of Georgia. To the north are the lower mountains of the Coast range, composed largely of granitic rocks, and to the south is the low area underlain by the relatively unresistent Eocene sediments, consisting largely of sandstones and conglomerates, only moderately disturbed, and well exposed in the shore cliffs [**9**]. The Eocene sediments are almost entirely covered with the thick deposit of clay, sand, and gravel comprising the Fraser River delta, built largely in post-Glacial times and recently uplifted some 400 feet (120 m.) and cliffed during the present marine cycle so that the old delta appears conspicuously

Miles and Kilometres.

to the east as the steamer sails south in the Strait of Georgia. The present delta of the Fraser forms an extensive lowland, only a few feet above sea level, that extends southwest from the older, uplifted delta.

To the west is Vancouver island, a good general view of which may be had in clear weather. The dark mass of the Vancouver range, composed largely of metamorphic and crystalline rocks, steeply surmounts the coast lowland, underlain by the less resistant sediments of the Nanaimo series. Most of the summits of the Vancouver range are rounded or ridge-like, but a few snow capped and serrated peaks are seen crowning the whole.

44 m. 71 km. **Active Pass**—Leaving the open Strait of Georgia the steamer enters Active Pass and for the next 25 miles (40 km.) sails through the relatively narrow, but deep, channels between the small islands off the southeast coast of Vancouver island. Active pass affords a section across the northeastward dipping upper members of the Nanaimo series, and is doubtless the result of the mature glaciation of a transverse pre-Glacial valley by one of the rapidly moving tongues of ice forced southward across the valley by the large southward-flowing Strait of Georgia glacier (**8**). An example of the rapid lateral gradation of the Nanaimo sediments, Northumberland formation [**5**], is here seen. To the northwest of the central part of the pass, on Galiano island, the sediments are chiefly conglomerates with some sandstones, while to the southeast along the line of strike on the shores of Mayne island in Miners bay, the same horizon consists chiefly of sandy shales, although there is no offset in the Pass. Since the dip of the sediments is about 20 degrees to the northeast, the northeast or back slopes of the islands have a cuesta form and are comparatively gentle, while the southwest or front slopes are steep

Crossing Trincomali channel, which is a drowned longitudinal anticlinal valley, the

Miles and Kilometres.

steamer enters Swanson channel between Prevost island on the northwest and Pender island on the southeast On these islands, the Nanaimo sediments, which are stratigraphically of a lower horizon than on Galiano and Mayne islands, are rather closely folded so that the dips are variable and fairly high. Seen in the background to the south and west of Prevost island is Saltspring island, the largest of the many islands off the east coast of Vancouver island. Its southern and central part is composed largely of the metamorphic rocks of the Vancouver group with intrusive bodies of granodiorite. Upon these the Nanaimo series lie unconformably, the basal members being stratigraphically considerably above the base of the series in other localities. The metamorphic and granitic rocks are seen surmounting the Nanaimo sediments, attaining an elevation of about 2,300 feet (700 m.), although the average elevation of the comparatively smooth top, which is a part of the uplifted Tertiary peneplain, is about 1,500 to 1,800 feet (450 to 540 m.). A low valley underlain by Nanaimo shales crosses the upland, and is bounded on the north by a steep slope. This slope, which is underlain by the metamorphic rocks with a cap of basal conglomerates, has been developed along an old fault, which separates the Nanaimo shales from the upthrown metamorphics. The original fault scarp was destroyed during the Tertiary erosion cycle, but after the uplift of the Tertiary peneplain, the less resistant Nanaimo sediments were more rapidly eroded leaving the metamorphics again in relief and producing a new scarp, a fault line scarp along the old fault.

Leaving Swanson channel, the steamer enters Moresby passage between Portland island to the west and Moresby island to the east. Both islands consist largely of the older metamorphics (Sicker series) and intrusive granodiorites, although small areas of Nanaimo sediments rest unconformably upon these older

Miles and Kilometres.

rocks. Farther to the northwest the same rocks form the southern part of Saltpsring island, whose southern slope is another fault line scarp, developed along a reversed strike fault parallel to that described above, and which has thrust the metamorphics against the Nanaimo sediments to the south. These sediments, which are folded into a closed syncline, overturned to the southwest, are exposed on the small islands to the south of Moresby passage, among which the steamer sails.

Leaving these islands the steamer enters the more open waters of Bayan bay. To the west is the town of Sidney, on the southeastern lowland of Vancouver island. This lowland, called here the Saanich peninsula, since it is separated by Saanich inlet from the upland of Vancouver island is underlain by the Saanich granodiorite, most o which is greatly fractured and altered. A less fractured portion of the granodiorite forms Mt. Newton, altitude 1,000 feet (305 m.), the largest monadnock of the vicinity, seen conspicuously to the southwest of Sidney. The sky-line of the upland which is the result of the mature-dissection of the uplifted Tertiary peneplain, is fairly even, the only pronounced irregularities being the large steep-sided valleys and occasional small monadnocks.

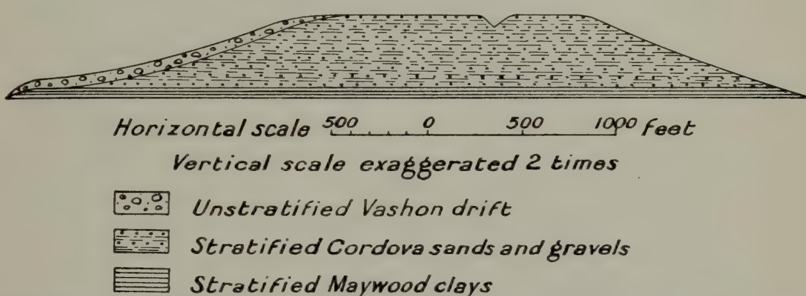
From Sidney channel between James island on the west and Sidney island on the east, the glacial deposits which mantle much of the southeastern lowland of Vancouver island are seen. Indurated rocks are not exposed on James island, and on Sidney island are exposed only in the southern part. The deposits, consisting of Maywood clays covered by Cordova sands and gravels, are chiefly inter-glacial and largely of marine origin. At the northern end of Sidney island is a brick plant which uses the Maywood clays. The inter-glacial deposits are strewn with large glacial boulders and are partly covered by the younger Vashon drift They were in part eroded during the Vashon

Miles and Kilometres.

glacial epoch, and upon the retreat of the Vashon glaciers the uneroded portions of the inter-glacial deposits were left as long, nearly straight, esker-like ridges, their axes having a general strike of S. 25° E. Since the retreat of the Vashon glaciers and the comparatively recent uplift these deposits have been rapidly retrograded into the steep cliffs about 100 feet (30 m.) high, which are seen on both James and Sidney islands. The retrograded material has been carried northward by the prevailing shore currents, building the long spits and beaches that are seen extending north from Sidney island. As the steamer leaves Sidney channel, the mature southern shore of James island is seen. Here the inter-glacial deposits have been retrograded, presumably for over a mile, resulting in a straight shore line with nearly vertical cliffs, which in the central portion is over 200 feet (60 m.) high. An idea of the rapidity of the retrogression of this shore is shown by a wire fence, which in 1907 was built to the edge of the cliff and which in 1910 had been undermined for 24 feet (7·3 m.) apparently not all at once but gradually, as that part of the cliff was retrograded uniformly with the rest. It is improbable however, that the entire shore-line is being retrograded at the rate of 6 feet (1·8 m.) a year, but the rate is doubtless more than one foot (0·3 m.). As a result of this retrogression a good section of the till-covered deposits is obtained, affording a proof of their inter-glacial origin, and of the fact that the inter-glacial drift ridges are erosion remnants of once more extensive deposits and are not constructional forms, since the outline of the present surface of the ridge cuts sharply across the bedding of the deposits. The southern shore of Sidney island is in marked contrast to that of James island, for on Sidney island the drift which doubtless originally covered the hard rocks, has been largely removed and a very irregular shore-line, still in an early stage, is the result. This has been called,

in order to show its analogy to a superposed valley, a contraposed shore-line.

Leaving Sidney channel, the steamer enters Haro strait between Vancouver island and San Juan island. To the east, the small D'Arcy islands, composed of the Vancouver volcanics, are seen, and to the west the retrograded inter-glacial deposits covering the southeastern part of the Saanich peninsula. To the



Section exposed along the south shore of James island, illustrating relation of superficial deposits.

southwest is a conspicuous monadnock, Mt. Douglas, altitude 725 feet (220 m.), which surmounts the lowland developed in the vicinity of Victoria.

Leaving Haro strait, the steamer passes between Vancouver island and several small islands, Discovery, Chatham, and Chain islands, which are composed largely of the Wark gabbro-diorite gneiss. Turning westward from these islands towards Victoria harbour the route follows for a short distance the great transverse downfold occupied by Juan de Fuca strait which lies between Vancouver island and the Olympic mountains to the south. The Olympic mountains, which are composed largely of pre-Tertiary metamorphics similar to the metamorphic rocks of Vancouver island fringed by upper Eocene basalts and Miocene sediments [**2** and **14**], seem to rise abruptly from sea-level to elevations of 6,000 to 8,000 feet (2,000 to 2,500 m.), their serrated peaks

Miles and Kilometres.

covered with large glaciers and snow fields. To the east on clear days may be seen the Cascade range of Washington with the denuded snow-and glacier-capped volcano, Mt. Baker, towering above the highest peaks for 4,000 feet (1,200 m.) and attaining an elevation of 10,694 feet (3,260 m.) To the northwest, the comparatively low, flat-topped, heavily wooded range of Vancouver island, attaining elevations from 1,500 feet (450 m.) to 3,000 feet (900 m.), forms the background, while in the foreground is the pre-glacial lowland of the vicinity of Victoria, surmounted by many small monadnocks.

Rounding Trial islands which ar composed of the Vancouve: meta-andesites, the steamer gradually turns northward and finally enters Victoria harbour, a comparatively narrow and small inlet, formed by the depression below sea-level of one of the submaturely glaciated valleys of the southeastern lowland. To the east is the city of Victoria, and to the west is the Esquimalt peninsula.

84 m. 135 km. **Victoria—**

GEOLOGY OF THE REGION AROUND VICTORIA.

Physiography.

The region around Victoria [4] consists almost entirely of the lowland developed in the southeastern part of Vancouver island during the pre-Glacial cycle. The lowland is not smooth, but, except where covered by drift deposits, is characterized by small irregular valleys and by a great number of rock ledges. The valleys are well adjusted to the weaker parts of the rocks, shear zones and joint planes, and frequently follow contacts, even where the contacts are irregular. The lowland is drained chiefly by numerous wet-weather streams with an intermittent flow, there being no larger rivers. Surmounting the lowland from 100 to 600 feet (30 to 180 m.) are numerous but relatively small monadnocks, and in th: western part

of the region is an upland transitional in character between the lowland and the upland of the Vancouver range, formed, as described, only by the mature dissection of the previously uplifted Tertiary peneplain. In the upland portion of the region around Victoria, the dissection of the Tertiary peneplain reached a further stage, one of late maturity, in which virtually, all of the uplifted peneplain was destroyed, although the region retains considerable relief. The monadnocks do not correspond with the outlines of the various rock formations, but have survived where the rocks were less fractured and sheared or less altered. Most of the monadnocks are roughly conical, but some are elongate, corresponding with the trend of their component rocks.

It was upon the lowland that the stratified drift was deposited during the inter-glacial period, the lowland having been previously scoured off by the southward flowing, piedmont, Strait of Georgia glacier, so that the elevations are now knob-like, with relatively smooth, rounded outlines. During the second period of glaciation, the stratified drift was partially eroded. This left long, esker-like ridges in the lea of some of the monadnocks, and in some of the eroded hollows in the drift mantle small lakes such as Swan and Lost lakes. In the upland portion the scouring action of the glaciers is more evident, especially of those valley glaciers that were confined between the sides of deep valleys, and here there are small lakes in deepened rock basins. Since the recent uplift the drift deposits have suffered little erosion, although in the western part of the region they have been terraced. In this locality the drift forms a wide, flat plain, from 200 to 250 feet (60 to 75 m.) above sea-level, known as Colwood plain.

It was apparently the depression of the glaciated and drift-covered lowland with numerous monadnocks, followed by a partial recovery, that formed the present irregular shore line and the numerous islands of the region. The initial shore line must have been rather simple, with smooth flowing outlines where the crystalline rocks were drift covered, but with many small, rounded and smoothed irregularities where the glaciated rock surfaces were not drift covered. During the present marine cycle, the shore has been subjected to moderately strong erosion, and the uplifted drift deposits have been rapidly retrograded to

form sea-cliffs 200 to 250 feet (60 to 75 m.) high with sand spits and bars, and in some places, as on the shore of Royal Roads, a nearly straight shore line. In many instances, as along the shore south of Victoria, the drift has been retrograded in places beyond the underlying rocks. The hard rocks form small, sub-sharp to rounded points, which project beyond the even, cliffed shore line. In other instances, as on the shore of Esquimalt peninsula, the drift has been largely removed, or else was never deposited and a very irregular shore line is the result. This irregular shore line, developed by retrogression of the drift cover, is in marked contrast to the simple retrograded type,and as already mentioned, in order to emphasize its analogy to the valley of a superposed river, has been called a contraposed shore line. The larger part of the coast is composed of resistant rocks, and virtually none of the initial irregularities of the depressed glaciated rock surface have been destroyed. On the contrary minor irregularities, such as small coves and wave chasms have been developed by wave action on the shear zones, joints, dykes, and interbedded softer rocks. The hard rocks themselves have not been beached, but since the retrograded drift deposits frequently occur between head lands of hard rock, narrow beaches composed of their material occur in the protected places of the headlands.

General Geology.

TABLE OF FORMATIONS.

Quaternary.

Superficial deposits.

Post-Glacial deposits	Recent.
Beach alluvium	
Valley and Swamp alluvium.	
Vashon Glacial deposits.	Pleistocene, later Glacial epoch.
Colwood sands and gravels	Stage of glacial retreat.
Vashon drift.	Stage of glacial occupation.
Puyallup inter-Glacial deposits.	Pleistocene.
Cordova sands and gravels	Inter-glacial epoch.
Maywood clays.	
Admiralty Glacial deposits.	Pleistocene.
Admiralty till.	Earlier Glacial epoch.

Shore south of Victoria, looking east to Finlayson point, showing development of contraposed shore-line. Hard rocks overlain by retrograded Vashon drift and Maywood clays.

	Tertiary.	
Metchosin volcanics.	Upper Eocene.	Ophitic basalt flows tuffs and agglomerates, with intrusive diabase dykes.
	Mesozoic.	
Batholithic and minor intrusives	Upper Jurassic and possibly Lower Cretaceous, correlated with Coast Range batholith.	
Diorite porphyrite		Dykes.
Saanich granodiorite		Stocks.
Colquitz quartz-diorite gneiss		Batholith of quartz--diorite gneiss, and quartz-feldspar (salic) and hornblendite (femic) facies, usually interbanded.
Wark gabbro-diorite gneiss.		Batholith of gabbro--diorite gneiss, with unfoliated gabbro and salic gabbro facies.
Vancouver group.	Jurassic and Triassic.	
Sutton formation.	Lower Jurassic possibly including Triassic.	Lentils of crystalline limestone in Vancouver volcanics.
Vancouver volcanics.	Lower Jurassic possibly including Triassic.	Metamorphic andesites, basalts, and olivine basalts, porphyries, amygdaloids, tuffs, and agglomerates and intrusivedykes and sills of basalt and andesite porphyrites.

Vancouver group—The metamorphic rocks of the region around Victoria are the Vancouver volcanics and the Sutton limestones, both of the Vancouver group and presumably of lower Mesozoic age. The Vancouver volcanics, the more important formation, consist largely of metamorphic flow rocks of medium basicity, meta-andesites, and some meta-basalts. Interbedded with the flow rocks are amygdaloids, and fragmental volcanics, tuffs and agglomerates, and cutting them all are dykes and sills of basalt porphyrite. All of the volcanics have been metamorphosed and greatly altered, the secondary

minerals being chiefly uralite, chlorite, epidote, calcite, and sericite. Such alteration is similar to that which takes place under conditions of moderate to shallow depths and moderate temperatures, and probably took place during the folding and shearing that the volcanics suffered in orogenic periods. However, near the contacts with the intrusive granitic rocks the volcanics have been greatly contact metamorphosed and some of them have even been recrystallized or replaced, forming various metamorphic types such as silicified and feldspathized varieties, amphibolites, and even garnet-diopside-epidote rocks. Analyses of the two last types are given below. The volcanics are also seamed with veins of quartz and of quartz and epidote, and in places are impregnated with metallic sulphides, chiefly pyrite.

	1.	2.
SiO_2	51·60	42·86
Al_2O_3	15·00	7·19
Fe_2O_3	1·85	14·24
$Fe\,O$	8·48	4·28
$Mg\,O$	7·15	2·96
$Ca\,O$	7·63	26·30
Na_2O	3·09	0·27
K_2O	0·70	0·33
$H_2\,O+$	1·95	1·00
$Ti\,O_2$	2·00	0·30
P_2O_5	0·18	0·21
$Mn\,O$	0·24	0·50
	99·87	100·44
Specific gravity	2·95	3·44

1. Amphibolite, Iron Mask Mineral claim, south of Mill hill, Esquimalt district. M. F. Connor, analyst.

2. Garnet-diopside-epidote rock, Iron Mask Mineral claim, Mill hill, Esquimalt district. M. F. Connor, analyst.

The Sutton formation is composed of crystalline limestone or marble, occurring as lentils intercalated in the Vancouver volcanics throughout their entire thickness. The lentils are small, only one of them, namely that extending from Esquimalt harbour west to Colwood plain, being over a mile long. The crystalline limestones are gray to grayish blue to white, compact to medium grained, and

where unmetamorphosed are composed almost entirely of calcium and magnesium carbonates, the former greatly predominating. The only impurities are small amounts of argillaceous and carbonaceous matter and pyrite. Near the intrusive granitic rocks the Sutton limestones have been contact metamorphosed into light coloured, coarsely crystalline marbles carrying diopside and wollastonite, and even into garnet-diopside-epidote rocks and silicified and mineralized varieties.

The following analysis is of a sample of limestone from Rosebank Lime Company's quarry half a mile west of Esquimalt harbour by F. G. Wait of the Department of Mines.

$CaCO_3$	95·35
$MgCO_3$	2·85
$Fe_2O_3+Al_2O_3$	0·16
Insol	1·95
S	tr.
P	tr.
	100·31

The Sutton limestones and Vancouver volcanics are in general contemporaneous and conformable, the limestones probably having been built by marine organisms that lived on the shores of volcanic islands formed during the eruption of the Vancouver volcanics. However, the actual contacts between the two formations are intrusive, the volcanics cutting the limestones. The intrusive contacts, which are also observed between the volcanic rocks themselves, do not indicate that the limestones are an older formation or necessarily occur near the base of the Vancouver volcanics, but merely indicate that intrusive volcanic types occur intermingled with the limestones as well as with one another.

The Vancouver volcanics and Sutton limestones have been greatly deformed, doubtless largely during the upper Jurassic orogenic period. The general strike of the rocks, which on account of their massive character were, for the greater part, presumably warped into large folds, is about N. 80° W., and the dips are usually steep. The original bedding of the rocks is almost completely obscured, but the rocks are foliated, and the foliation and bedding appear

to be virtually conformable. In some instances the foliation is nearly north to south, which indicates that small folds occur. The rocks have also yielded by fracturing, shearing, and faulting.

During and following the upper Jurassic orogenic period, the Vancouver volcanics and Sutton limestones were invaded by granitic rocks and their accompanying minor intrusives, and at the contacts the volcanics were greatly shattered, cut by apophyses, and, as mentioned, greatly metamorphosed. The granitic rocks may be subdivided into three main types, irrupted in a definite sequence as follows: Wark gabbro-diorite gneiss; Colquitz quartz-diorite gneiss; and Saanich granodiorite. The minor intrusives, most of which accompanied the irruptions of the Saanich granodiorite, consist of dykes and small injected bodies of diorite porphyrites.

Batholithic and minor intrusives.

The Wark and Colquitz gneisses form virtually a single batholith, with a general northwest-southeast strike, corresponding with the strike of the Vancouver volcanics. The Wark gneiss is a dark greenish rock of medium to coarse grain and gneissic texture, consisting essentially of light greenish weathering plagioclase (labradorite-andesine) and hornblende, and since it is intermediate in composition between a gabbro and a diorite is classed as a gabbro-diorite. The following is an analysis of a typical sample.

SiO_2	48·68
Al_2O_3	18·05
Fe_2O_3	3·41
FeO	6·44
MgO	2·82
CaO	10·00
Na_2O	3·18
K_2O	1·60
H_2O+	2·40
TiO_2	0·80
P_2O_5	2·01
MnO	0·20
	99·59
Specific gravity	2·91

Wark gabbro-diorite gneiss. One half mile south of Mt. Tolmie, Victoria district. M. F. Connor, analyst.

Fine grained phases of the Wark gneiss occur as segregations or inclusions in the normal rock, especially near the contacts with the intrusive Colquitz gneiss and Saanich granodiorite. In places they form bands parallel to the foliation, but more commonly they form irregularly shaped masses sometimes several yards in width, which frequently are elongated in a direction transverse to the foliation. The normal gabbro-diorite is not only gneissic but considerably altered and more or less metamorphosed, especially near the contacts with younger granitic rocks, where there have been developed certain metamorphic varieties with large and frequently poikilitic hornblendes or varieties in which recrystallized hornblende greatly predominates.

The Colquitz gneiss is a gray, medium grained rock of gneissic to schistose texture, consisting essentially of altered plagioclase (andesine), quartz, hornblende, and biotite, and is classed as a quartz diorite although it contains much more quartz than the average quartz diorite. At one locality the gneiss is a biotite granite. The Colquitz gneiss has also certain salic and femic facies. The salic facies is light coloured, consisting essentially of quartz and feldspar, while the femic facies is dark, consisting almost entirely of hornblende, thus forming hornblendites. The facies commonly occur interbanded, the separate bands or masses varying from a fraction of an inch up to several feet in width, thus producing a conspicuously banded gneiss. The larger femic bands are virtually always coarsely crystalline.

The following analyses are of the Colquitz gneiss:—

	1	2	3
$Si\,O_2$	64·04	75·02	38·80
Al_2O_3	15·83	13·90	12·50
Fe_2O_3	2·16	0·45	6·57
$Fe\,O$	2·40	0·40	8·20
$Mg\,O$	2·72	0·10	13·10
$Ca\,O$	3·60	1·16	11·42
Na_2O	3·52	3·06	1·60
$K_2\,O$	1·43	5·37	0·81
$H_2\,O+$	1·60	0·95	2·85
$Ti\,O_2$	0·30	0·04	1·60

P_2O_5	1·56	0·15	1·26
MnO	0·15	0·10	0·23
	99·31	100·70	98·94
Specific gravity	2·74	2·63	3·16

1. Unbanded Colquitz quartz-diorite gneiss, Smiths Hill, Victoria district. M. F. Connor, analyst.

2. Salic facies of Colquitz gneiss, north of Prospect lake, Lake district. M. F. Connor, analyst.

3. Coarse grained facies (hornblendite) of Colquitz gneiss. Northwest of Prospect lake, Lake district. M. F. Connor, analyst.

The youngest granitic rock, the Saanich granodiorite, forms a stock underlying the southwestern part of Esquimalt peninsula, and other smaller stocks. It is a light coloured, medium-grained rock, frequently having a somewhat gneissic texture and consisting essentially of feldspar, orthoclase and andesine, quartz, and accessory hornblende, and usually biotite. The granodiorite contains also numerous small rounded segregations, darker coloured than the normal rock and consisting chiefly of plagioclase and hornblende. An analysis of a rather basic phase of the Saanich granodiorite is given below.

SiO_2	62·64
Al_2O_3	17·75
Fe_2O_3	1·64
FeO	3·44
MgO	2·53
CaO	4·44
Na_2O	3·53
K_2O	2·14
H_2O+	1·65
TiO_2	0·60
P_2O_5	0·25
MnO	0·14
	100·75
Specific gravity	2·71

Saanich granodiorite, south shore of Shoal harbour, North Saanich district, M.F. Connor, analyst.

The diorite porphyrites usually form fairly well defined and regular dykes, from a few inches up to 50 feet (15 m.) in width, largely confined to the vicinity of the contacts of the Esquimalt stock. They are greyish green, porphyritic rocks, with an aphanitic groundmass and phenocrysts of feldspar, hornblende, and sometimes augite.

All of the irruptive rocks have been more or less foliated, the gneisses greatly. The strike of the foliation is predominantly northwest-southwest, generally near N. 60° W, but varies widely. The rocks are also greatly jointed and fractured, and in places sheared. They are altered and, especially near the shear zones, are mineralized and cut by small and irregular quartz and quartz-epidote veins, but contain no mineral deposits of commercial value.

Although the Wark and Colquitz gneisses form virtually a single batholith, the Colquitz gneiss is distinctly intrusive into the Wark gneiss, the contacts being marked by wide zones of shatter breccias and numerous aplitic and a few pegmatitic apophyses of the Colquitz gneiss. Although in places cross cutting, the apophyses are usually injected parallel to the foliation, and are foliated themselves parallel to their walls. In some instances the apophyses, parallel to the foliation, are so numerous as to convert the gabbro-diorite gneiss into a banded gneiss resembling the banded Colquitz gneiss. Also the Wark gneiss is cut by large masses of the Colquitz gneiss, usually the salic facies, some of which are several hundred feet in width. The contact zones are sometimes sheared and foliated and the angular xenoliths of the gabbro-diorite gneiss in the quartz diorite gneiss have been pulled out into dark femic bands These strongly resemble the femic bands of the Colquitz gneiss, but in part perhaps differ from them by being occasionally broken or cut across the foliation by the quartz diorite. The relatively few dykes of pegmatite are unfoliated, and, while usually parallel to the foliation, are sometimes cross cutting.

The banded Colquitz gneiss, in particular that type with the wide, coarse grained, femic bands or masses, is more or less restricted in its occurence to the contacts with the intruded Wark gneiss. As described, its salic and femic bands vary in didth from a fraction of an inch to 4 or 5 feet (1·2 or 1·5 m.), and possibly to several feet.

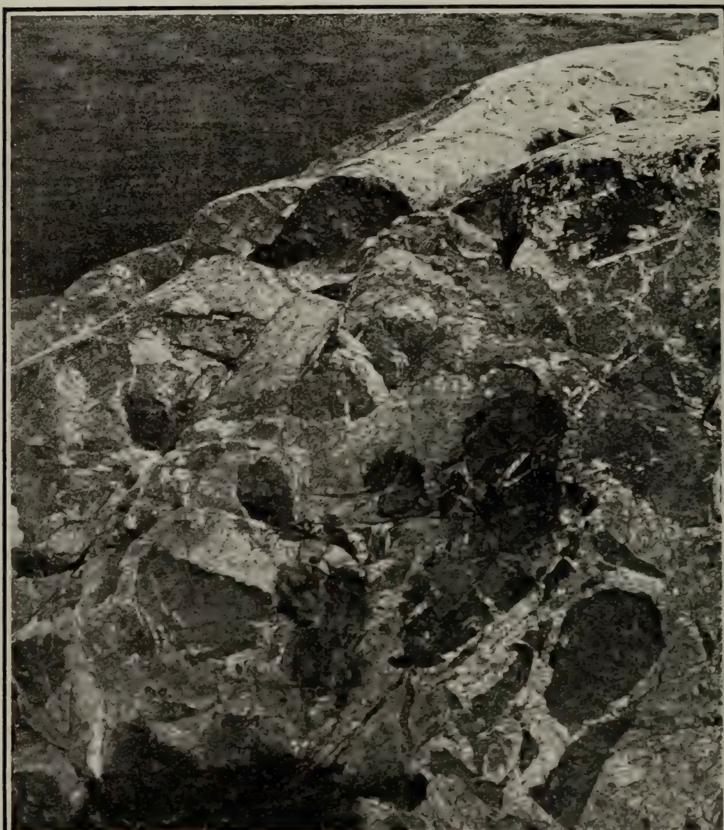
The length of the individual bands is more or less proportional to their width. Some of the bands, especially the narrower and finer grained, gradually pinch out, but others, notably the wider, coarser grained ones, end abruptly and irregularly. The sides of the bands are usually straight but are sometimes broadly curved and more rarely contorted. The contacts between the bands, while usually well marked, are not sharp in detail, but the crystals of one band are intergrown with those of the continuous bands. In places the Wark gneiss appears to be cut not only by salic apophyses of the Colquitz gneiss but by hornblendite apophyses, which seem to be intrusive and cross cutting. The relations however are so complex and the resemblance of the supposed hornblendite apophyses to the recrystallized Wark gneiss is so close that the intrusive nature of the hornblendite masses can not be positively affirmed. It is concluded that the banded Colquitz gneiss is of primary origin; that in part the salic and femic bands are true magmatic differentiates, the intrusive magma having been split into the salic and femic facies before it became too viscous for the separated facies to be pulled out into bands by continued movements in the differentiated magma; and that some of the wide, coarser grained bands are recrystallized and pulled out inclusions of the Wark gneiss.

The Saanich granodiorite is clearly intrusive into the Wark gneiss and doubtless is younger than the Colquitz gneiss. It brecciates the Wark gneiss, forming extensive areas of "contact complex", consisting of shatter breccias and networks of granodiorite and aplite apophyses in the gabbro-diorite gneiss.

The diorite porphyrites are younger than the granitic rocks. It is seen that the eruptive cycle, represented by all of the igneous rocks, the Vancouver meta-volcanics, the granitic rocks, and the diorite porphyrites, conforms to the general eruptive cycle, which consists of three phases of igneous activity in the following sequence: the volcanic phase; the batholithic phase; and the phase of minor intrusives.

The granitic rocks were irrupted into the rocks of the Vancouver group apparently in a relatively quiet manner, and have replaced them without disturbing them greatly. The invading magmas, even during their last active stages, shattered the invaded rocks along their contacts into angular fragments. Near the present contacts great

numbers of these fragments occur in the intrusive rocks but disappear within a few yards. They may have been shattered to smaller fragments and assimilated by the intrusive rocks while still in a magmatic condition, for of



Contact shatter breccia at contact of Wark gabbro-diorite gneiss and Saanich granodiorite, showing both angular and rounded xenoliths; ledge south of Outer wharf, Victoria.

this there is some evidence, or they have sunk in the intrusive magma to abyssal depths. Possibly it was by this last method that the granitic rocks replaced large volumes of the rocks into which they were intrusive.

As described, the granitic rocks were not irrupted at the same time, but during two main periods, which have

been called the Wark and Saanich periods. During the first period, the Wark and Colquitz gneisses were irrupted, but independently, thus dividing the Wark period into two sub-periods, the second sub-period being characterized by the irruption of a more salic magma than that irrupted during the first. The close relationship of the Wark to the Colquitz gneiss shows, however, that they are closely related in origin, and are doubtless differentiates of the same parent magma. A similar subdivision characterizes the Saanich irruptive period, but the first sub-period, during which the femic Beale diorite was irrupted, is not well represented near Victoria. Also the rocks irrupted during the Wark and Saanich periods are closely related structurally, and, except that those of the Wark period are gneissic, are similar lithologically. It is probable, therefore, that the Wark and Saanich magmas were themselves differentiates of the same parent magma, the Wark magma being more basic then the Saanich magma. Since the principal rock types have been separately, and more or less independently, intruded in large masses, the differentiation producing the various types must have been deep seated. Since the parent magma was apparently subdivided into the Wark and Saanich magmas, each of which independently underwent further differentiation under deep seated conditions, it seems probable that this differentiation did not take place in the same magma chamber. It looks as if the Wark and Saanich magmas after differentiation from the parent magma were irrupted from the primary magma chamber into separate chambers, where each underwent its further differentiation, producing the sub-types which were themselves irrupted independently into their present position. It also appears as if the three principal types were still further differentiated, apparently "in place", giving rise to the minor variations of the principal rock types.

Metchosin volcanics.—Confined to the western part of the region and separated from the other crystalline rocks by the thick deposit of sand and gravel of the Colwood delta, are the Metchosin volcanics. They are all basic, chiefly basalts and diabases, the latter occurring as dykes in the basalts. The basalts vary from coarsely porphyritic and ophitic varieties to amygdaloids, and frequently exhibit pillow and columnar structures. They are interbedded with fragmental varieties, ranging from fine tuffs

Pillow structure in Metchosin basalts. Islets off south shore of Albert head, Vancouver island.

to very coarse agglomerates. Some of the fragmental rocks are waterworn, and at least one bed of tuff is fossiliferous. The fossils, which are chiefly Eocene gastropods, give the only evidence of the age of the volcanics and place them definitely in the upper Eocene. The same fossil-bearing tuffs are found to the south on the Olympic peninsula [**14**]. It is probable that the eruptions of the Metchosin basalts were largely of a quiet nature from numerous fissures, and actual vents are doubtless represented by diabase dykes. That the eruptions were in part explosive is fully substantiated by the occurrence of agglomerates and tuffs, and it is possible that the irregular masses of coarse agglomerate represent the pipes or necks of old volcanic cones. The absence of terrestial sediments in the volcanics and the presence of marine organisms suggests that the volcanics were accumulated under marine conditions, presumably in deep water removed from any continental mass. But the occurrence of waterworn fragments and of marine fossils indicates that enough lava was erupted to form a platform which reached nearly to the surface of the water, and on which were built the cones that projected above sea level.

The Metchosin volcanics have been deformed and more or less altered. They have a general northwest-southeast strike and are evidently involved in several folds although the prevailing dip is about 30 degrees to the northeast. They are extensively sheared and faulted, and their northern contact is a profound thrust fault, which extends for 40 miles (64 km.) across the southern end of the island. Farther west they are also intruded by gabbro masses. The deformation and intrusion must have taken place at or near the close of Eocene times, for farther west the deformed and intruded rocks are unconformably overlain by Miocene sediments. Some of the alteration of the Metchosin volcanics must have taken place during the deformation, but much of it has taken place under surface conditions developing zeolites and similar secondary products.

Superficial Deposits—The drift deposits of the region are of varied character, having been deposited by various agencies during the different stages of glacial occupation and retreat [**7** and **8**]. The oldest of the superficial deposits, the Admiralty till, is confined to a few localities and occurs in the crevices and small irregular hollows of

the glaciated crystalline rocks, and is only a few feet in thickness. It varies from an unstratified, hard, yellowish gray, sandy clay, with subangular to rounded pebbles, to rudely stratified, coarser, yellow clayey sand, with scattered pebbles and subangular boulders.

The Puyallup inter-glacial deposits are chiefly well stratified clays, sands, and gravels usually found below elevations of 250 feet (76 m.) In general, the clays occur near the base of the deposits, and the sands and gravels near the top, so the deposits are subdivided into the Maywood clays and the Cordova sands and gravels. The Maywood clays are chiefly bluish or yellowish gray, sandy clays with numerous, irregularly distributed, subangular to rounded, undecomposed pebbles and boulders of crystalline rocks. They are well stratified and frequently contain layers of sand and occasionally of gravel. The clays are frequently carbonaceous, and plant impressions and remains are common in them. Impressions and occasional shells of marine organisms, chiefly small molluscs, are also found in them. The Maywood clays sometimes rest upon the Admiralty till, but more commonly lie directly on glaciated surface of the crystalline rocks. They vary greatly in thickness, depending partly upon the irregularities of the underlying rock surface, but they probably average as much as 100 feet (30 m.).

The Cordova sands and gravels consist of yellow to grayish yellow, medium to coarse grained, and usually pebbley sand, with irregular lentils and interbeds of gravel, and towards the base, interbeds sometimes 10 to 15 feet (3 to 4·5 m.) thick of sandy clay or rarely stiff blue clay. They also contain a few, irregularly distributed, small glacial boulders. The pebbles are usually fresh, but in some instances the coarser grained granitic pebbles have been entirely decomposed. The sands are well stratified,but are usually cross bedded, and exhibit instances of contemporaneous erosion and deposition. They also contain marine organisms, which are however very fragile. The Cordova sands and gravels, averaging 200 feet (65 m.) in thickness, overlie the Maywood clays, and usually form low ridges that were left in relief by the erosion of wide valleys between them by glaciers of the Vashon period Some of the ridges occur in the lea of the larger monadnocks.

The Vashon drift is ordinarily an unsorted till, with numerous undecomposed granitic boulders. In some places the finer materials of the drift are rudely stratified. Near the surface it is usually oxidized to dark brown, and passes into a dark, sandy and gravelly loam, which usually covers it. The drift seldom forms distinct and characteristic topographic features such as moraines, but is merely a mantle covering the crystalline rocks and the inter-glacial deposits. Below elevations of 250 feet (80 m.) except in restricted localities, the mantle is thin, seldom more than 3 or 4 feet (·9 to 1·2 m.) thick. Frequently it thins out so completely that over large areas it is absent or is represented only by glacial boulders, which are strewn over the surface of the inter-glacial deposits. Above elevations of 250 feet, (80 m.) the larger part of the entire drift mantle is the Vashon till, although it is probably mixed with more or less of the Admiralty till.

In the western part of the region is a deposit of sand and gravel about 200 feet (60 m.) thick, which forms a plain, the smooth Colwood plain, two to three miles (3 to 5 km.) wide and from 200 to 250 feet (60 to 80 m.) above sea level. On it are well defined terraces up to 20 feet (6 m.) high, and near its inner border are several kettle holes, the largest of which are 100 to 800 feet (30 to 250 m.) across and 10 to 80 feet (3 to 25 m,) deep. The deposit consists chiefly of coarse sands and gravels, which are well stratified and have a pronounced delta structure, the larger part of the deposit consisting of fore-set beds with dips of 15 to 25 degrees to the southeast. These are capped with 10 to 15 feet (3 to 5 m.) of top-set beds of horizontally stratified coarse gravels.

Since the superficial deposits described above are of glacial origin a discussion of their origin together with a description of the glaciation of the region is necessary. The lowland portion of the region was overridden by the southward flowing, piedmont, Strait of Georgia glacier. The results of the severe abrasion of the hard rocks by the glacier are most striking [**7**]. The rocks are not only smoothed, but are striated and grooved, the grooves even in the crystalline rocks attaining a width of 3 to 5 feet (·9 to 1·5 m.) and a depth of 1 to 5 feet (·3 to 1·5 m.). The striations and grooves are not confined to the flat surfaces, but occur also on the sloping and vertical ones, in some instances the rocks being actually undercut.

These features, and curved and spreading striations, indicate the remarkable "plasticity" of ice under great pressure. The smaller ledges have been worn into roches moutonnées, and although their lea ends are usually broad and craggy, they are in places smoothly polished and striated. The abrasion has been greatest on the soft rocks, and has left rounded ledges of the hard rocks in relief. Many of the rounded points of the shore line are of this nature. The general direction of movement seems to have been slightly west of south. Locally, owing to the influence of topography, the movement appears to have varied considerably from this direction. The influence of the topography varied at successive stages of glaciation, and as a result cross striations were produced. The direction of the grooves varies only from 10 to 20 degrees from south, but that of the striations, which frequently cross the grooves and are later, varies at least from S. 50° E. to S. 35° W. This fact indicates that the minor topographic features had little effect on the glacial movement until the stage of glacial retreat. The only superficial deposit formed during this period of glaciation is the Admiralty till. It was doubtless more extensive than appears at present, and probably furnished a large part of the material of the inter-glacial deposits and, as mentioned, may occur on the upland mingled with the Vashon drift. It was deposited directly by ice, some of it being clearly a ground moraine, but part of it was apparently deposited in water, probably below sea-level.

On the retreat of the Admiralty glaciers the land stood at least 200 feet (60 m.) lower than at present, since marine fossils occur in the inter-glacial deposits up to that elevation. Presumably the drowned pre-Glacial lowland formed estuaries, and in these estuaries, under conditions of comparative quiet and of moderate temperature, the Maywood clays were deposited. The glaciers had not, however, completely disappeared from the region as the irregularly distributed pebbles and large erratic glacial boulders in the clays testify, since they were doubtless dropped from floating ice. During the later stages of the inter-glacial epoch, when the Cordova sands and gravels were being deposited, either shallower water prevailed or else the rivers and streams issuing from the ice front, perhaps advancing at this time, were more heavily laden with coarser detritus.

During the epoch of Vashon glaciation, the Vashon drift was deposited largely by ice alone, but doubtless in part by water. The Vashon galciers were smaller than those of the Admiralty period, for the Vashon drift rests directly upon the hard glaciated rocks in the upland regions only, since the piedmont glaciers, which over-rode the lowland, were unable to remove the covering of inter-glacial deposits, eroding merely portions of these deposits.

To judge from the absence of moraines of Vashon drift, the retreat of the Vashon glaciers must have been fairly rapid. Nevertheless the Colwood delta was doubtless formed at the front of one or more of the retreating glaciers, presumably in salt water. This delta has since been uplifted about 250 feet (80 m.).

Particular Descriptions.

Excursion C 1. (First Day).

From the Empress hotel the route of the excursion lies along the shore south of Victoria to Oak bay and across the cities of Oak Bay and Victoria, stops being made at various points of interest.

Locality 1.—Contact shatter-breccia of Wark gabbro-diorite gneiss and Saanich granodiorite, cut by complex of diorite porphyrite dykes. Minor faulting. Glacial scouring, roches moutonnées, deep grooves, and striations. General view of contraposed shore-line.

Locality 2.—Good view to the east of an irregular rocky (contraposed) shore line. Hard rocks overlain by retrograded Vashon drift and Maywood clays.

Locality 3.—Contact complex and shatter breccia of Vancouver meta-andesite, Wark gabbro-diorite gneiss, and Saanich granodiorite. Aplitic apophyses with quartz segregations and quartz veinlets. Hybridism. Breccia foliated and slightly faulted. Glacial grooving and striation. East to Clover point, submaturely retrograded portion of shore line. Clover point, hard rock headland showing beginning of contraposition.

Locality 4.—Between 3 and 4 pre-Glacial lowland covered by Maywood clays with a thin mantle of Vashon drift and frequent outcrops of Vancouver meta-volcanics. To the south Gonzales hill, altitude 215 feet (65 m.) a monadnock surmounting the lowland.

Vancouver meta-volcanics, foliated flow-breccia. Roches moutonnées, grooving, and crossed striations.

Locality 5—Between 4 and 5 pre-Glacial lowland of Maywood clays with thin mantle of Vashon drift and numerous outcrops of Vancouver meta-andesites. Foliated, contact metamorphosed Vancouver volcanics, cut by a great number of quartz-feldspar masses and irregular apophyses of quartz-diorite.

Locality 6.—Contact complex of Vancouver meta-andesites and Wark and Colquitz gneisses. Hybridism and primary gneisses.

Locality 7—Between 6 and 7 pre-Glacial lowland with small glaciated monadnocks and ledges chiefly of Wark gabbro-diorite gneiss.

Road-cut in drift, showing relations of Admiralty till, Maywood clays, and Vashon till.

Excursion C 1 (Second Day).

From the Empress hotel the route of the excursion lies north and west of Victoria to a number of points of geolo--gical interest.

Locality 8—Vashon drift, unconformably overlying Cordova sands and gravels, which overlie Maywood clays. Latter not exposed here. Sand and gravel pits, from which material is obtained for mortar, concrete, filling, etc.

Locality 9—Between 8 and 9, pre-Glacial lowland largely covered by Maywood clays, few outcrops of Wark and Colquitz gneisses.

Mt. Tolmie, altitude 383 feet (95 m.), a monadnock of Wark gabbro-diorite gneiss, protected the Cordova sands and gravels from erosion during Vashon glaciation. Section of drift and Cordova sands and gravels. Sand and gravel bank.

Locality 10—Between 9 and 10 pre-Glacial lowland with numerous small monadnocks and large ledges, chiefly of Wark gneiss.

View of wooded "train" of Cordova sands and gravels in lea of large monadnock, Mt. Douglas or Cedar hill, altitude 725 feet (220 m.).

Locality 11—From 10 along wooded "train" of Cordova sands and gravels to top of Mt. Douglas.

Wark gabbro-diorite gneiss, cut by aplite veins. General view of pre-Glacial lowland, uplifted Tretiary peneplain—

the Vancouver Island upland—,Pacific Coast and Juan de Fuca downfolds, and Coast range and Olympic mountains.

Locality 12—From 11 to 12 across pre-Glacial lowland with numerous ledges of Wark and Colquitz gneisses.

Sharp contact of Wark and Colquitz gneisses. Coarse grained, recrystallized phases, and fine grained segregations of Wark gabbro-diorite. Pegmatite dykes. Foliation. Glacial grooves, striations, and roche moutonnée.

Locality 13—From 12 south to Victoria and across Esquimalt peninsula, pre-Glacial lowland with numerous small monadnocks or ledges of the crystalline rocks, but largely covered by Maywood clays with a thin mantle of Vashon drift in places. To east and west of Esquimalt peninsula the drowned submaturely glaciated valleys of Victoria and Esquimalt harbours. To northwest, upland, formed by late mature dissection of uplifted Tertiary peneplain, transitional in character to the Vancouver Island upland.

Quarry in Sutton limestone. Limestone used for flux by Tyee Copper Company's smelter at Ladysmith. Dyke of sheared basalt porphyrite of Vancouver volcanics.

Locality 14—Sutton limestone lens in contact with Saanich granodiorite. Apophyses of granodiorite and irregular dykes of basalt porphyrite. In places limestone contact metamorphosed, silicified, and converted into garnet-diopside-epidote rock, with small body of magnetite and chalcopyrite. Limestone quarried for manufacture of lime.

Locality 15—Between 14 and 15, Colwood delta.

Section of Colwood delta showing top-set and fore-set beds. Hydraulicking of deposit for sand and gravel, used for concrete, filling, etc.

Locality 16—From 15 across Colwood delta and Albert head. Headland composed of Metchosin volcanics.

Metchosin basalts. Tuffs and agglomerates, some with water worn fragments, "concretions," and "bombs." Vesicular and amygdaloidal basalts. Diabase dykes and pipes. Denuded volcano (?). Columnar jointing. Fossiliferous tuffs (upper Eocene gastropods). Secondary minerals, calcite, quartz, and zeolites. Glacial grooves, striations, and roches moutonnées.

Locality 17—Metchosin basalts, columnar jointing and pillow structure.

Locality 18—From 17 back on to Colwood delta.

Kettle or ice block holes near inner border of delta. Large ledges of Metchosin basalts to west.

Locality 19—From 18 across terraced Colwood delta. Iron Mask mineral claim on south slope of Mill hill, altitude 631 feet (195m). Contact metamorphosed Vancouver andesites, amphibolites, which have been sheared, solicified, and mineralized, cut by quartz veinlets, and replaced by garnet-diopside-epidote rock, with magnetite, pyrrhotite, pyrite, and chalcopyrite.

Locality 20—To the west Sutton limestone quarried for the manufacture of lime. Lime hydrated and used in the manufacture of sand-lime brick. Sand from Colwood sands and gravels.

Locality 21—Unfoliated shatter breccia of Wark and Colquitz gneisses. Hybridism and development of hornblendite.

Locality 22—Banded Colquitz quartz diorite gneiss, primary gneiss. Small pegmatite dykes, small faults and contortions.

Locality 23—From 22 over pre-Glacial lowland. Numerous ledges of Wark gneiss and small monadnock, Knocken hill, to north, altitude 260 feet (79 m.), and drowned glaciated valley, Portage inlet, to south.

Pot-hole in Wark gabbro-diorite gneiss, formed by glacial stream descending through a crevasse or by inter-glacial stream. Wark gneiss cut by apophyses of Colquitz quartz diorite.

Locality 24—From 23 over pre-Glacial lowland, largely covered by Maywood clays with thin mantle of Vashon drift in places, and a few outcrops of Wark gneiss.

Maywood clays. Clays used for the manufacture of common brick and tile. Marine fossils.

Excursion C 2 (Section I.)

From the Empress Hotel the excursion proceeds west across the Esquimalt peninsula, which is a portion of the pre-Glacial lowland, with numerous small monadnocks or ledges of the crystalline rocks, largely covered by Maywood clays, with a thin mantle of Vashon drift in places. To the east and west of Esquimalt peninsula the drowned submaturely glaciated valleys of Victoria and Esquimalt harbours. To northwest, upland formed by

late mature dissection of uplifted Tertiary peneplain, transitional in character to the Vancouver Island upland.

Locality 1—Quarry in Sutton limestone. Limestone used for flux by Tyee Copper Company's smelter at Ladysmith. Dyke of sheared basalt prophyrite of Vancouver volcanics.

Locality 2—Sutton limestone lens in contact with Saanich granodiorite. Apophyses of granodiorite and irregular dykes of basalt porphyrite. In places limestone contact metamorphosed, silicified, and converted into garnet-diopside-epidote rock, with small body of magnetite and chalcopyrite. Limestone quarried for manufacture of lime.

To the southwest, Sutton limestone quarried for the manufacture of lime. Lime hydrated and used in the manufacture of sand-lime brick. Sand from Colwood sands and gravels.

Locality 3—From 2 across Colwood delta.

Section of Colwood delta showing top-set and fore-set beds. Hydraulicking of deposit for sand and gravels, used for concrete, filling, etc.

Locality 4—From 3 across Colwood delta and Albert head. Headland of Metchosin volcanics.

Metchosin basalts. Tuffs and agglomerates, some with water worn fragments, "concretions", and "bombs". Vesicular and amygdaloidal basalts. Diabase dykes and pipes. Denuded volcano (?). Columnar jointing. Fossiliferous tuffs (upper Eocene gastropods). Secondary minerals, calcite, quartz, and zeolites. Glacial grooves, striations, and roches moutonnées.

Locality 5—Metchosin basalts, columnar jointing and pillow structure.

Locality 6—From 5 back on to Colwood delta.

Kettle or ice block holes near inner border of delta. Large ledges of Metchosin basalts to west.

Locality 7—Unfoliated shatter breccia of Wark and Colquitz gneisses. Hybridism and development of hornblendite.

Locality 8—Banded Colquitz quartz diorite gneiss, primary gneiss. Small pegmatite dykes, small faults and contortions.

Locality 9—From 8 over pre-Glacial lowland.

Numerous ledges of Wark gneiss and small monadnock, Knockan hill to north, altitude 260 ft. (79 m.), and drowned glaciated valley, Portage inlet to south.

Pot hole in Wark gabbro-diorite gneiss, formed by glacial stream descending through a crevasse, or by inter-glacial stream. Wark gneiss cut by apophyses of Colquitz quartz diorite.

Locality 10—From 9 over pre-Glacial lowland, largely covered by Maywood clays with thin mantle of Vashon drift in places and a few outcrops of Wark gneiss.

Maywood clays. Clays used for the manufacture of common brick and tile. Marine fossils.

Excursion C 2, (Sections I and II).

Leaving the Empress hotel the entire excursion proceeds along the shore south of Victoria to Oak bay, stopping at various points of interest, and then returns to Victoria, via Mt. Tolmie.

Locality 11—Contact shatter breccia of Wark gabbro-diorite gneiss and Saanich granodiorite, cut by complex of diorite porphyrite dykes. Minor faulting. Glacial scouring, producing roches moutonnées, deep grooves, and striations. General view of contraposed shoreline.

Locality 12—Good view to the east of an irregular rocky, contraposed shore line. Hard rocks overlain by retrograded Vashon drift and Maywood clays.

Locality 13—Contact complex and shatter breccia of Vancouver meta-andesite, Wark gabbro-diorite gneiss, and Saanich granodiorite. Aplitic apophyses with quartz segregations and quartz veinlets. Hybridiom.

Breccia foliated and slightly faulted Glacial grooving and striation. East to Clover point, submaturely retro-graded portion of shore line. Clover point, a hard rock headland, showing beginning of contraposition.

Locality 14—Between 13 and 14 pre-Glacial lowland covered by Maywood clays with a thin mantle of Vashon drift and frequent outcrops of Vancouver meta-volcanics. To the south Gonzales hill, altitude 215 feet (65 m.), a monanock surmounting the lowland.

Vancouver meta-volcanics, foliated flow-breccia. Roches moutonnées, grooving, and crossed striations.

Locality 15—Between 14 and 15 pre-Glacial lowland of Maywood clays with thin mantle of Vashon drift and numerous outcrops of Vancouver meta-andesites. Foliated, contact metamorphosed Vancouver volcanics, cut by a

great number of quartz-feldspar masses and irregular apophyses of quartz diorite.

Locality 16—Contact complex of Vancouver meta-andesites and Wark and Colquitz gneisses. Hybridism and primary gneisses.

Locality 17—Between 16 and 17 across pre-Glacial lowland largely covered by Maywood clays, few outcrops of Wark and Colquitz gneisses.

Mt. Tolmie, altitude 383 feet (95 m.), a monadnock of Wark gabbro-diorite gneiss cut by pegmatite and aplite dykes and quartz veins. Grooving and striations. Cordova sands and gravels in lea of monadnock protected from erosion during Vashon glaciation. Section of Vashon drift and Cordova sands and gravels. Sand and gravel bank. General view of pre-Glacial lowland and uplifted Tertiary peneplain—the Vancouver Island upland—, Pacific Coast and Juan de Fuca downfolds, and Coast range and Olympic mountains.

Locality 18—From 17 to 18 pre-Glacial lowland largely covered by Maywood clays, few outcrops of Wark and Colquitz gneisses.

Vashon drift, unconformably overlying Cordova sands and gravels, which overlie Maywood clays, Latter not exposed here. Sand and gravel pits. Sand and gravel used for mortar, concrete filling, etc.

ANNOTATED GUIDE.

(Vancouver to Nanaimo.)

Excursion C 2, Section II.

Miles and Kilometres.

0 m.
0 km.

Vancouver—Leaving Vancouver the steamer sails westward through the narrow pass called the First Narrows, at the entrance of Vancouver harbour, into the Strait of Georgia. To the north are the lower mountains of the Coast range, composed largely of granitic rocks, and to the south is the low area underlain by the relatively unresistent Eocene sediments, consisting largely of sandstones and conglomerates, only moderately disturbed, and well exposed in

Miles and Kilometres.

the shore cliffs [9]. The Eocene sediments are almost entirely covered with the thick deposit of clay, sand, and gravel comprising the Fraser River delta, built largely in post-Glacial times and recently uplifted some 400 feet (120m.) and cliffed during the present marine cycle, so that the old delta appears conspicuously to the south as the steamer sails west across the open waters of the Strait of Georgia. The present delta of the Fraser forms an extensive lowland, only a few feet above sea level, that extends south from the older, uplifted delta.

To the west is Vancouver island. In clear weather a good general view of it may be had. The dark mass of the Vancouver range, composed largely of metamorphic and crystalline rocks, steeply surmounts the coast lowland which is underlain by the less resistant sediments of the Nanaimo series. Most of the summits are rounded or ridge-like, but a few snow capped and serrated peaks are seen crowning the whole.

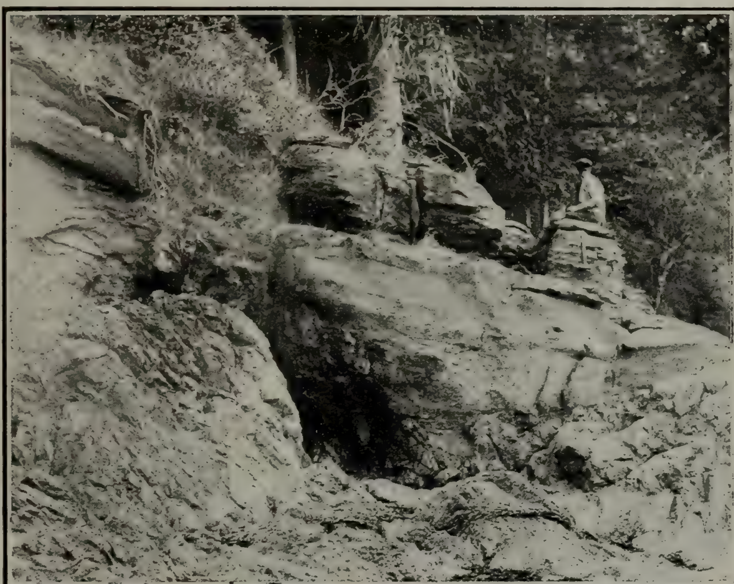
After crossing the Strait of Georgia, the steamer enters Fairway channel between Entrance and Gabriola islands to the south and Snake island to the northwest. These islands are built of the upper formations of the Nanaimo series, which are here involved in a large syncline pitching to the north. Turning south, the steamer sails along a drowned valley largely underlain by shales, between sandstone islands, Gabriola island to the east and Newcastle and Protection islands to the west. Rounding the southern point of Protection island, on which is seen the surface workings of the Protection shaft of the Western Fuel Company's collieries, the steamer enters Nanaimo harbour. Directly to the west is the city of Nanaimo,

41 m. 66 km. **Nanaimo**—built on the coastal lowland of sedimentary rocks of the Nanaimo series. In the background is Mt. Benson, 3,300 feet high (1,000 m.) composed of Vancouver volcanics, around which the Nanaino series forms a narrow fringe.

GEOLOGY OF THE REGION AROUND NANAIMO.

PHYSIOGRAPHY.

The region around Nanaimo (**5**) is a part of the east coast lowland of Vancouver island. Since the sedimentary rocks underlying the lowland are varyingly resistant, as well as moderately disturbed, their predominating strike



Basal unconformity, shore west of Neck point, Wellington district, showing the irregularities of the surface on which the Nanaimo series was deposited.

being northwest and their dip northeast, the lowland has considerable relief, extensive valleys having been developed in belts of soft rocks, between ridges composed of more resistant beds. The hard rock ridges are of the cuesta type with very steep, in places nearly vertical, front slopes and gentle dip or back slopes. Tongues of the crystalline rocks extend eastward from the upland to the west, and form low eastward trending ridges increasing in elevation to the westward. One of the ridges in the northern part of the region forms the northern boundary of the sedimentary rock basin, and another west of Nanaimo is

the flank of Mt. Benson. It appears as if the eastern part of the Nanaimo basin had been depressed below sea level, and the valleys drowned to form the long, wide channels, passes, and harbours of the region. The hard rock ridges remain above sea level as long points and islands. During the Glacial period the region was glaciated, and the rock surfaces were smoothed, and the valleys deepened. Upon the retreat of the glaciers the region apparently stood a few hundred feet lower than at present, for up to an elevation of 400 feet (120 m) occur stratified sands and gravels, in part of marine or estuarine origin. A recent uplift has brought the land into its present position, and initiated the present erosion cycle, during which the revived streams have terraced the superficial deposits, and have cut narrow canyons in the indurated rocks, while the superficial deposits fronting on the coast have been retrograded to form cliffs up to 100 feet (30 m.) in height.

General geology.

The crystalline rocks, upon which the coal bearing sediments of the Nanaimo series rest unconformably, are the Vancouver meta-andesites. The volcanic rocks were greatly deformed, metamorphosed and intruded by granitic rocks, probably in late Jurassic time. The granitic rocks were subsequently exposed, since boulders and pebbles of them occur in the sediments of the Nanaimo series. However, the crystalline rocks were apparently not worn down to a lowland, because the surface upon which the sedimentary rocks were deposited is seen to be one of considerable relief. Small irregularities are directly observable in exposed unconformities, and the contacts of the Nanaimo series with the underlying rocks, where not disturbed by intense folding and faulting, follow very closely the contours of present elevations, which must have been elevations at the time of deposition also, unless far more irregular and complex folding than is elsewhere observed is supposed.

The Nanaimo series, as shown by its fauna, is partly of marine origin, probably estuarine, since it was deposited

on a surface of considerable relief, and under varying conditions, as shown by the rapid lateral and vertical gradation of the sediments. The series also contains land plants and coal, probably of fresh water accumulation. Hence conditions of fresh or at least brackish water, that is, terrestrial conditions, alternated with marine conditions. The upper part of the Nanaimo series, however, contains few or no marine organisms, the only fossils being a few obscure plants. It is possible therefore, that the alternating conditions recorded in the lower part of the Nanaimo formation were finally replaced entirely by terrestrial conditions. The lithological character of the sediments—the sandstone being composed of angular to sub-angular fragments and of a large percentage of easily decomposed minerals such as feldspar—indicates a very rapid accumulation and deposition in relatively small basins, where the detritus was not subject to severe wave action. The sedimentation began in Upper Cretaceous time, at a stage corresponding with the Chico, or the Pierre, and it appears as if the sediments were first deposited in a marine basin, between the mainland and Vancouver island, which basin was probably one of deformation, depressed at least as early as the upper Jurassic. During the deposition, the sedimentation trangressed inland, at first filling up the irrgularities of the pre-Upper Cretaceous erosion, and then possibly covering even the higher residual elevations. The total thickness of the Nanaimo series was near 10,000 feet (3,000 m.) toward the close of its deposition, at which time it extended far inland over the denuded crystalline rocks covering the greater part of the island, or was perhaps restricted to large depressions.

The conditions of deposition in the northwestern part of the Nanaimo basin, where the coal deposits occur, appear to have been more uniform than these which existed elsewhere, for there the series may be subdivided solely on a lithological basis into various formations each with its more or less peculiar characteristics. The formations are enumerated and their thickness and general lithological character given in the following table:—

Formation	Lithology	Thickness. Minimum. Feet.	Minimum. Metres.	Maximum. Feet.	Maximum. Metres.	Average. Feet.	Average. Metres.
Gabriola formation	Chiefly sandstones	1,400	426	1,400	426	1,400	426
Northumberland formation	Conglomerates, sandstones and shales	1,100	335	1,200	365	1,150	350
De Courcy formation	Chiefly sandstones	800	243	1,400	426	850	259
Cedar district formation	Chiefly shales	700	213	1,000	304	750	228
Protection formation	Chiefly sandstones	600	182	750	228	650	198
Newcastle formation (Douglas coal seam) (Newcastle coal seam)	Fine conglomerates and sandy shales, contains Douglas seam	150	45	400	122	200	61
Cranberry formation	Flaggy and shaly sandstones and sandy shales, gritty sandstones and fine conglomerates	150	45	500	152	250	76
Extension formation (Wellington coal seam)	Chiefly conglomerates, also shales, and sandstone horizons and small coal seams	700	213	1,500	457	800	243
Eastwellington formation	Sandstone	35	10	50	15	35	10
Haslam formation (marine shales) (Departure Bay calcarenites)	Chiefly shales	500	152	800	243	600	182
Benson formation	Basal conglomerate	0	0	400	122	100	30
Total		6,125		9,400		6,785	

In general the conglomerates are composed chiefly of quartz and quartzose rocks; the sandstones chiefly of granitic detritus, quartz and feldspar; and the shales chiefly of volcanic detritus, being grayish green in color. From the mere statement of these facts, which constitute a rather peculiar feature of the lithology, a simple yet fairly plausible explanation suggests itself. Of all the underlying rocks whose detritus composes the sediments, the volcanic rocks alone were chemically disintegrated, and their detritus, being very fine grained, was deposited as mud which now forms the shales. The granitic rocks were mechanically disintegrated, and broken down into a coarse feldspathic sand, furnishing the material for the sandstones. The quartz veins and the quartzose rocks, however, were broken down only into a coarse rubble to form the material for the conglomerates.

A peculiar feature of the shale horizons of the upper part of the Nanaimo series, especially of those characterized by a large number of small sandstone interbeds, is the occurrence of numerous sandstone dykes. These cut the shales at all angles to the bedding. They are fairly regular, although branching and offset by faults. The larger, 3 to 4 feet (·9 to 1·2 m.) thick, may be traced for at least 100 feet (30 m.). Although they cut the shales sharply, apparently along joint planes, the shales are frequently bent or slightly contorted next to the dykes. On the shores, where the dykes are best exposed, on account of their greater resistance to wave erosion, they stand above the shales, forming low walls, the highest wall noted being three feet (9 m.).

As a rule the dykes are finer grained than the sandstone interbeds, and the cementing material is more calcareous but in general the two are of similar material. Indeed, in many instances, dykes protrude from the sandstone interbeds, and there are off-shoots from the dykes conformable with the bedding of the shales, that simulate the appearance of sandstone interbeds, but are recognized as off-shoots by occurring usually on one side of the dyke only. There are also other smaller and more irregular off-shoots into the shales, resembling small apophyses from an igneous dyke.

From their occurrence and close resemblance to other intrusive sandstone dykes, their origin is in little question. They appear to have been formed by the injection of soft

sands which were forced usually upward along joint planes in the shale, the injection being similar to that of an igneous dyke. After the injection the sands were firmly cemented by calcium carbonate, precipitated from water circulating through the relatively coarse grained dyke. One important conclusion to be drawn from their occurrence is that movement must have taken place while at least the upper sandstones of the Nanaimo series were in a soft and plastic condition.

Another feature indicates that movement took place while the sediments of the upper part of the series were in a plastic condition. Even in the coarser, most massive beds, such as thick bedded conglomerates, sudden folds or sharp rolls occur, although the beds may be otherwise only moderately disturbed. These rolls, which are really more of the nature of small displacements or faults, are so pronounced that a bed which has a moderate dip in one direction may turn down at right angles, so that the dip of the down-turned portion is vertical and its strike is at right angles to the strike of the bed as a whole. The largest of these sharp rolls, exposed on the west shore near the northern end of Newcastle island, occurs in a coarse grained, thick-bedded conglomerate, and the width of the down-turned portion is about 150 feet (45 m.). In spite of the magnitude and abruptness of the displacement, there is not the slightest indication of extra jointing, shearing, or slickensiding. Instead the fold has occurred as if the conglomerate were as plastic as wet clay. Hence unless we hypothecate more intense folding than is observed and a much thicker cover, which would induce greater pressure, this type of fold can be explained only by the supposition, that the conglomerates and other sediments which have suffered in the same way, were soft and plastic when the folding took place.

The Nanaimo series was subjected to strong orogenic movement also, presumably during the post-Eocene deformation, the deforming forces apparently having their origin to the northeast, probably below the basin between Vancouver island and the mainland. The series was deformed into broad open folds, complicated by small closed folds and reversed faults, the latter largely restricted to the western boundary of the basin. The axes of folding have a

general northwest-southeast strike, and the prevailing dip is to the northeast. At the northern rim of the basin in the vicinity of Departure bay, the general strike turns from northeast to east, while the dip is to the southeast and south. The largest fold, with the exception of the major fold which outlines the basin, occurs on Gabriola island. It is a syncline, which is divided into two parts by a transverse anticlinal roll at the northern end of the island.

A large portion of the region about Nanaimo is covered by superficial deposits of various kinds, which are, however, almost entirely referable to the Glacial period. This period was characterized by two epochs of glacial occupation, the Admiralty and the Vashon, separated by an inter-glacial epoch, the Puyallup. Little or nothing remains of the glacial till, which must have mantled a large part of the area on the retreat of the earlier and larger Admiralty glaciers. During the Puyallup inter-glacial epoch, a large part of the lowland must have been covered by stratified sands and clays, partly, if not entirely, of marine origin. These inter-glacial deposits were largely eroded during the Vashon glaciation, but now occur mantled by a more or less persistant covering of Vashon drift, to the northwest of Nanaimo and in the broad low area adjoining the lower part of the Nanaimo river, to the south of Nanaimo. On the retreat of the Vashon glaciers, large delta deposits, composed chiefly of sand and gravel, were built at the mouths of the large valleys, which extend eastward from the Vancouver Island upland, and were at that time presumably occupied by retreating valley glaciers. The deposits have a maximum elevation of about 400 feet (120 m.). The islands are not covered by these deposits but merely by debris of the immediately underlying rocks mixed with more or less glacial till and sometimes overlying or closely associated with stratified sand and clay of the inter-glacial deposits. It thus appears as if during the deposition of the delta deposits the islands were still covered by the piedmont Strait of Georgia glacier. It may be that the deltas were deposited in lakes dammed by the Strait of Georgia glacier, but, since it is positively known by the occurrence of marine fossils in the vicinity (on Texada island and near Vancouver) at elevations near 400 feet (120 m.) that a recent uplift of about 400 feet

(120 m.) has occurred, it is more probable that the deltas were deposited in the salt water. As already mentioned, since the uplift the delta deposits have been terraced and retrograded.

The other superficial deposits consist of recent swamp, valley, delta, and beach alluvium.

Geology of the Coal Deposits.

There are at present three productive coal seams in the Nanaimo district lying in the following succession from the bottom upwards: the Wellington; the Newcastle, sometimes called the lower Douglas; and the Douglas. The lowest seam, the Wellington, occurs about 700 feet (210 m.) above the base of the Nanaimo series, overlying 600 feet (180 m.) of marine sandy shale, the Haslam formation. The Newcastle and Douglas seams, are only from 25 to 100 feet (8 to 30 m.) apart, and overlie the Wellington seam by about 1,000 feet (300 m.), separated from it chiefly by a thick bedded conglomerate, the Extension formation. A fourth and small seam, called the little Wellington, locally overlies the Wellington at a distance of 20 to 50 feet (6 to 15 m.). It has been mined in a small way.

The coals of the various seams are as a whole much alike, and furnish a bituminous coal of fair grade. The amount of fixed carbon in the best quality ranges from 45 to 60 per cent, and the ash from 5 to 10 per cent. The following proximate and ultimate analyses were made by F. G. Wait of the Department of Mines, from samples collected by the writer.

ANALYSES.

Proximate.	1.	2.	3.
Analysis by fast coking.			
Water	1·65	1·16	1·54
Vol. combust	43·25	40·47	33·30
Fixed carbon	45·52	50·04	56·23
Ash	9·24	7·80	8·44
Sulphur	1·24	0·53	0·49
	100·	100·	100·
Coke	55·38	58·11	64·91
Character of coke	firm, coherent.	firm, coherent.	firm, coherent.
Fuel ratio	1·07	1·23	1·65
Split volatile ratio	2·92	3·29	4·00

Ultimate.	1.	2.	3.
Carbon	72·80	75·53	74·46
Hydrogen	5·17	5·13	5·42
Nitrogen	0·88	1·19	1·37
Oxygen	10·67	9·82	9·82
Sulphur	1·24	0·53	0·49
Ash	9·24	7·80	8·44
	100·	100·	100·

No. 1. Coal from the Wellington seam.
No. 2. Coal from the Wellington seam.
No. 3. Coal from the Douglas seam.

The most striking feature of the seams is their great variability in thickness and quality. The thickness varies from nothing to over 30 feet (10 m.), sometimes within a lateral distance of less than 100 feet (30 m.). This variation is caused by irregularities in either the roof or

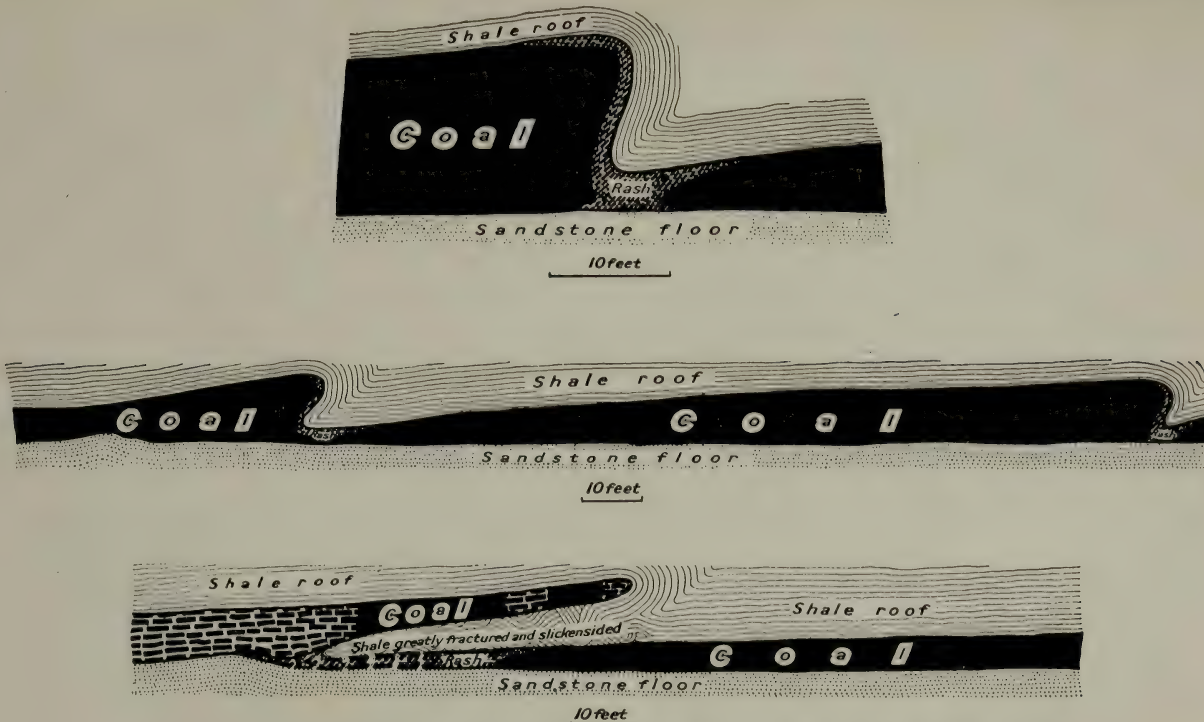
floor, and occasionally in both. In quality the seams vary from where they are entirely composed of clean, bright coal, with about 5 per cent ash, to where they are entirely composed of a dirty slickensided coal, locally called "rash," with over 50 per cent ash. The following is a proximate analysis of the rash from the Wellington seam.

PROXIMATE ANALYSIS BY FAST COKING.

Water	1·59
Vol. combust.	24·15
Fixed carbon	19·29
Ash	54·97
Sulphur	undet.
	100·

The Wellington seam rests on a firm sandstone floor, which is fairly regular although a few sharp rolls do occur in it. The roof, however, varies greatly in character from sandy shale to conglomerate, with many irregularities, especially in the sandy shale. The average thickness of the seam is from 4 to 7 feet (1 to 2 m.), but it occasionally pinches to virtually nothing, and then suddenly thickens to 10 or 12 feet (3 or 4 m.). The floor may be nearly smooth, but the roof in passing from the thin to the thick portion of the seam rolls upward sharply and often irregularly. Occasionally the roof is overturned forming in one instance an overlap in the seam of at least 25 feet (8 m.). These sharp rolls are locally called "faults." Invariably at the thin places or "pinches" the coal is dirty and slickensided, while in the thick places or "swells" it is clean, black in colour with a sub-brilliant lustre, and broken only by a few irregular joints. Rash is usually found near the top and bottom of the swells and rarely in thin partings near the centre. Even in the swells some bone is present as small lenses seldom more than a quarter of an inch thick. In some instances the coal is clean and unfractured against the upturned roof, but more commonly it is somewhat slickensided and even contorted. The roof at the rolls is always contorted and slickensided.

The strike of the rolls corresponds with the strike of the measures, that is, northwest to west, and the pinches occur in the northeast and north side of the rolls with the corresponding swells on the opposite side. Where the



Sections of the Wellington seam, showing rolls and overlaps. Where represented as broken, seam inferred.

seam is overlapped, the overlap is to the northeast or north.

These features are illustrated by the accompanying sections which are drawn to scale.

It appears from the evidence given above as if the variation was due in large part to a folding which affected the coal seams when the clean coal was in a fairly plastic condition. This conclusion is especially well substantiated in another part of the Wellington seam, where it is composed of several sub-seams separated by dirty slickensided coal or rash. During the deposition of the seam, conditions in which fairly clean carbonaceous matter was deposited must have alternated with those during which the carbonaceous matter was deposited with a large amount of silt. When the seam was folded, the clean coal was apparently forced away from the tight bends, where the folding caused an increase in the vertical pressure, and left the seam at these places composed almost entirely of rash. The clean coal flowed to where there was a corresponding relief of vertical pressure forming a swell where the seam, except for the rash at the top and bottom, consists chiefly of clean bright coal.

Besides the barren places or wants due to folding subsequent to the deposition of the seam, there are large wants due solely to silting, for in some instances the silting must have persisted throughout the period of coal formation. Also large and persistent partings of shale occur between the sub-seams.

Both types of variation occur in the Douglas seam. The seam varies from nothing to 30 feet (10 m.) in thickness, and averages about five feet (1·5 m.) although over large areas the average thickness of the mineable coal is between three and four feet (·9 and 1·2 m.). The floor of the Douglas seam is usually a rather weak sandy shale, and the roof, although stronger, is very variable, ranging from a sandy shale to a fine grained conglomerate, the principal type being a shaly sandstone with sandstone layers and lenses of fine grained conglomerate. Unlike the conditions in the Wellington seam the pinches and swells are caused chiefly by irregularities in the floor, the roof being fairly smooth. At the pinches the seam is composed almost entirely of rash, like that of the Wellington seam, although as a rule it is harder. The coal occurring in the swell has a compact texture, but rather dull lustre. It is irregu-

larly broken into large blocks. Near the pinches some of the coal is slickensided and contorted, but where these features are shown the coal contains a higher percentage of ash. The coal seam is displaced also by small faults, although an actual break seldom occurs, the coal having been forced along the plane or zone of dislocation. Rarely the entire seam folds or wrinkles without any appreciable variation in thickness.

The Newcastle seam is more regular than the Wellington or Douglas seams, but is thinner, varying, as far as known, from 20 to 45 inches (0·51 to 1·15 m.) where mined, and contains more numerous and more regular partings. It is also less extensive in area than the other two seams.

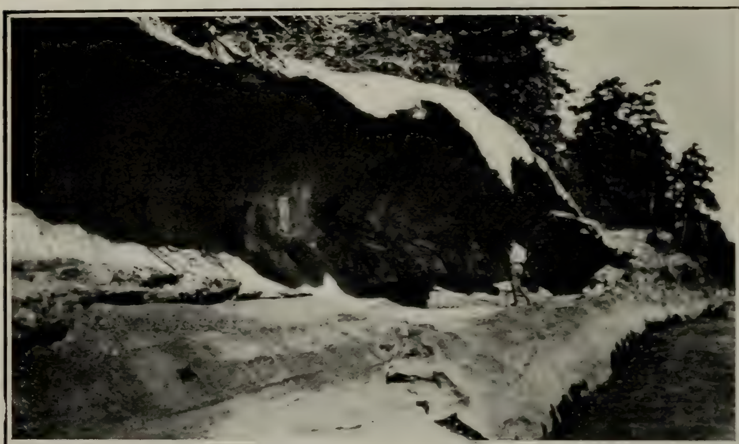
The coal has been the source of a flourishing industry for over 50 years. The Wellington seam has been mined at Wellington, Northfield, East Wellington, Harewood Plains, and Extension, and is at present mined by the Vancouver-Nanaimo Coal Mining Company at East Wellington and by the Canadian Collieries (Dunsmuir) Company near Extension. The Newcastle and Douglas seams, which are usually worked together, have been mined extensively in the vicinity of Nanaimo. The mines here are operated by the Western Fuel Company. There has also been a large production from the Douglas seam south of Nanaimo, notably at Chase River, Southfield, and South Wellington. In these localities the Newcastle seam, although readily located, is of doubtful value. There is only one mine producing at present in this district, the South Wellington mine, operated by the Pacific Coast Coal Mines. Both the Western Fuel Company and the Pacific Coast Coal Mines are sinking new shafts along the lower part of the Nanaimo river to open up the Douglas seam in depth. The present coal production is over 1,000,000 tons per year, and the importance of the Nanaimo district in the coal industry may be more readily comprehended when it is realized that it produces over one third of the entire coal output of British Columbia.

PARTICULAR DESCRIPTION.

From Nanaimo an excursion is made eastward across Nanaimo harbour to Gabriola island. To the south are the wharfs and coal bunkers of the Western Fuel Company.

The inner part of the harbour is underlain by Protection sandstone, exposed to the north on Newcastle and Protection islands. On Protection island, Protection island shaft, cutting the Douglas seam at 588 feet (179 m.) and the Newcastle seam, at 652 feet (199 m.). Outer part of harbour and Nanaimo valley to the south underlain by Cedar District shales.

Jack Point cuesta composed of DeCourcy sandstones, which dip north of east at an angle of 25 degrees.



Galiano (Malaspina) Gallery.

Northumberland channel underlain by lower shale horizon in the Northumberland formation.

West shore of Gabriola island, cuesta of Northumberland sandstones, dipping north of east at an angle of 10 degrees. Honeycomb weathering.

Decanso bay. Upper shale horizon of the Northumberland formations, underlying concretionary Gabriola sandstones Sandstone quarry.

Along shore of cuesta-like ridges of northeastward dipping Gabriola sandstone. Angle of dip averages 15 degrees.

Locality 1—Galiano (Malaspina) Gallery. Gabriola sandstone, weathered by solution and wind.

Tinson point. Highest beds of Nanaimo series in the vicinity of Nanaimo, nearly 5,000 feet (1,500m.) to Douglas seams. Thin bedded Gabriola sandstones dipping north

at an angle of about 5 degrees. Small bays on either side of point formed in a shaly horizon in Gabriola formation.

Lock bay. Northumberland shales dipping northwest at an angle of about 15 degrees below Gabriola sandstone. From Locality 1 across northward pitching syncline. Transverse anticline crosses Gabriola syncline, which to the south pitches southeast.

Locality 2—Northumberland shales dipping southeast at angle from 10 to 15 degrees, overlain by Gabriola sandstones, exposed in cliff, one quarter of a mile back from shore. Shales with sandstone interbeds and sandstone dykes.

Locality 3—Snake island. Honeycomb and "gallery" weathering of concretionary Gabriola sandstone dipping eastward at an angle of 25 degrees.

Locality 4—Islands and headland of Vancouver volcanics to north, evidently a headland of those rocks that projected into the basin in which the Nanaimo series was deposited. Unconformity, showing irregular surface upon which Nanaimo series was deposited, and coarse basal conglomerates (Benson formation) Departure Bay calcarenites.

Locality 5—From 4 across Departure bay, underlain by Haslam, Extension, and Cranberry formations, which have here a minimum thickness. To the west retrogarded inter-glacial deposit. Abrupt downfold in conglomerate and coarse sandstone of the Cranberry formation.

Locality 6—From 5 through Newcastle Island channel, crossing Newcastle and Douglas seams at narrows. Brechin mine of Western Fuel Company to the west, and old slopes on the two seams to the east.

Quarry in Protection sandstone.

Along Newcastle Island channel to Nanaimo, near contact of Newcastle and Protection formations.

East Wellington Mine—Wellington seam reached through an inclined shaft, paralleling an old slope driven on the little Wellington seam. Wellington seam in mine fairly flat, with low dip from 5 to 10 degrees to the northeast, but to the southwest the seam is faulted in a series of steps, and outcrops at the surface to the southwest of the surface plant with a steep dip to the northeast. Sharp rolls or "faults", smooth sandstone floor, but irregular sandy shale roof, in places overturned. Few small rolls in sandstone floor. Faults in southern part of the mine.

(Nanaimo to Victoria).

Miles and Kilometres.

0 m.
0 km.
Nanaimo—Altitude 133 feet (40m.). From Nanaimo the railroad runs south, and for about two miles follows closely the outcrop of the Douglas seam. To the west may be seen one of the recently abandoned slopes on the Newcastle seam. Farther west is the drift covered lowland terminated by the steep slope of Mt. Benson. Farther south near Chase river the outcrop of the coal seams swings to the east, and to the west are the bare back slopes of the cuestas of Extension conglomerate, which dip northeast toward the railroad.

3·3 m.
5·3 km.
Stark Crossing—Altitude 80 ft. (24 m.). At Stark Crossing the railroad turns and runs east for three quarters of a mile (1 km.), and then again follows the outcrop of the Douglas seam south by east for two and a half miles (4 km.). Immediately to the west are the ruins of the old Southfield mine, and a half a mile north of South Wellington is one of the mines now operated by the Pacific Coast Coal Mines, the coal being brought to the surface through two slopes on the seam.

5·3 m.
8·5 km.
South Wellington—Altitude 124 ft. (37 m.). At South Wellington is the abandoned Alexandria mine. To the east is the steep front slope or cliff of the cuesta formed by the northeastward dipping Protection sandstones, and to the west across the alluvial-filled, submaturely glaciated valley, formed along the outcrop of the Douglas and Newcastle seams, and in which is situated Cranberry lake, is the back slope of a cuesta of conglomerate of the Cranberry formation. To the south the railroad, after crossing the railroad of the Pacific Coast Coal Mines cuts through the lower part of the white weathering Protection sandstone, and for over a mile runs in places along the back slope of the Protection

Miles and Kilometres

sandstone cuesta. Just before crossing the Nanaimo river, a quarter of a mile north of Cassidy Siding, the railroad runs on to the Nanaimo delta, built at the mouth of the upper part of the Nanaimo River valley, during the recession of the Vashon glaciers and terraced by the recently revived river. Along its present course the revived stream has cut a narrow canyon, 80 feet (24 m.) deep, in the Protection sandstone.

Cassidy Siding—Altitude 132 ft. (40 m.). At Cassidy Siding the Protection sandstone cuesta is seen to the west; to the east are the low terraces of the Nanaimo delta, and still farther east is the drift-filled, glaciated valley formed in the Cedar district shales. To the south the railroad crosses two branches of Haslam creek, which here splits into two or three channels while crossing one of the broad terraces of the Nanaimo delta. South of Haslam creek the railroad traverses the Nanaimo delta nearly to Ladysmith.

10·9 m.
17·5 km. **Brenton**—Altitude 95 ft. (30 m.). North of Brenton a cuesta of Protection sandstone is seen east of the track. To the southwest beyond the terraced delta is the monadnock, Mt. Hayes, elevation 1,450 feet (442 m.), composed of Saanich granodiorite, and almost entirely surrounded by the Haslam shales, and hence presumably an island during the deposition of the lower members of the Nanaimo series. From Brenton to Ladysmith the railroad is parallel to the Extension railroad of the Canadian Collieries Company, over which the coal from the Extension mines is brought to Ladysmith. To the north of Ladysmith, the railroad cuts through the Protection sandstone, which has here a nearly vertical dip, the base on which the Nanaimo series rests occurring only a mile to the west.

14·1 m.
22·7 km. **Ladysmith**—Altitude 83 ft. (25 m.). To the east is Ladysmith harbour, the drowned southern portion of the glaciated valley developed in the Cedar District shales. Beyond the

Miles and Kilometres.

harbour is the Woodley range,a cuesta developed on the northeastward dipping DeCourcey sandstones. At Ladysmith are the copper smelter of the Tyee Copper Company and the wharfs and washer of the Canadian Collieries Company. South of Ladysmith the railroad closely follows the coast, the coast lowland being but one or two miles wide. To the east glimpses are had of the drowned portion of the lowland. To the west the Vancouver Island upland steeply surmounts the lowland and almost directly west of Chemainus, is Mt. Brenton nearly 4,000 feet (1,200 m.) high.

21·3 m.
33·8 km. **Chemainus**—Altitude 109 ft. (33 m.). South of Chemainus the lowland widens again to four miles (6·4 km.), and is drained by the Chemainus river. It is largely drift covered and wooded, and only a few outcrops are seen.

25·7 m.
41·4 km. **Westholme**—Altitude 29 ft. (9 m.). South of Westholme the railroad enters a wide flat-bottomed valley, the northern part of which between Mt. Richards, 1,100 feet (340 m.) high on the east and Mt. Sicker, 2,400 feet (730 m.) on the west, is underlain by the Nanaimo sediments. The Nanaimo sediments almost surround the northern part of Mt. Richards, having been deposited around it while the mountain itself remained above sea-level as an island or peninsula. Both Mt. Richards and Mt. Sicker are composed of the more or less mineralized schistose and intrusive rocks of the Sicker series, a few outcrops of which occur in the southern and narrowest part of the valley. On Mt. Sicker occurred the Tyee-Lenora lens of copper ore. The Lenora railroad, extending from the mine to Crofton, and now used as a lumber railroad, is crossed a mile beyond Westholme, and at Tyee the aerial tram of the Tyee Copper Company comes down from Mt. Sicker.

28·1 m.
45·2 km. **Tyee**—Altitude 129 ft. (39 m.). South of Tyee the railroad cuts through some deformed black slaty shales. To the west on Mt. Prevost, 2,643 feet (806 m.) high, these shales

Miles and Kilometres. are unconformably overlain by conglomerate, apparently of the Nanaimo series, and still farther west in the valley of Chemainus river the shales grade northward into the Sicker schists. They are presumably of Jurassic or Triassic age, but are indistinguishable from the Nanaimo shales which occur to the east below the drift-covered flat extending from the railroad to the shore.

29·9 m.
48·1 km. **Somenos**—Altitude 108 ft. (33 m.). From Somenos to south of Cowichan the railroad crosses the large, maturely glaciated, subsequent Cowichan valley, underlain by a closely folded syncline of Nanaimo sediments, largely sandstones and shales. The valley is almost 50 miles (80 km.) long, and nearly divides the southern part of Vancouver island. It is glacially deepened, especially in its upper part, where Cowichan lake lies. The Cowichan river flows eastward from the lake, and for the greater part of its course meanders in its flat valley floor, some two to three miles wide, between cut banks 10 to nearly 200 feet (3 to 60 m.) high, of stratified drift of inter-glacial and post-glacial deposition, the river having been revived by the recent uplift. At Somenos is a brick plant using the inter-glacial clays, which cover a large part of the lower portion of the valley.

32·8 m.
52·8 km. **Duncan**—Altitude 50 ft. (15 m.). Between Somenos and Duncan, to the east of the railroad, is Somenos lake, formed in one of the partly drained hollows in the inter-glacial clays. East from Duncan is Mt. Tzuhalem, which is capped by the basal conglomerates of the Nanaimo series resting unconformably on the Sicker schists and porphyrites. The southern slope is a fault line scarp, developed along the fault which has thrown the Sicker series up against the Nanaimo series to the south. Farther to the east is Saltspring island, composed largely of the rocks of the Sicker series. The greater part of the island has an elevation of 1,500 to 1,800 feet (450 to 540 m.) and is a

Miles and Kilometres.

remnant of the uplifted Tertiary peneplain. Its southern slope is a fault line scarp, developed along the eastward continuation of the fault mentioned above.

34·4 m. 55·4 km. **Koksilah**—Altitude 28 ft. (9 m.).

37·0 m. 59·6 km. **Cowichan**—Altitude 119 ft. (36 m.).

38·4 m. 61·8 km. **Hillbank**—Altitude 150 ft. (46 m.). North of Cowichan is a quarry in the Nanaimo sandstones, which are seen to be underlain by shales. The last exposures of the Nanaimo sandstones are seen to the north of Hillbank.

41·3 m. 66·5 km. **Cobble Hill**—Altitude 315 ft. (96 m.). To the west of Cobble Hill station is Cobble hill, 1,100 feet (355 m.) high, which with the exception of the northern slope underlain by Saanich granodiorite, is composed of Vancouver metavolcanics, which form a belt 2 to 20 miles (3 to 30 km.) wide extending to the west coast. Numerous outcrops of the volcanics are seen near the railroad to the south of Strathcona and along the northern shore of Shawnigan lake, although the volcanics are largely covered by Vashon till. Just to the south of Strathcona is a small lentil of Sutton limestone which is intercalated in the Vancouver volcanics.

44·7 m. 71·4 km. **Koenig**—Altitude 390 ft (119 m.).

Strathcona—Altitude 456 ft. (139 m.).

25 Mile Post—Altitude 553 ft. (168 m.). Shawnigan lake has been formed in the glacially deepened portion of one of the mature, transverse, north-south valleys, which dissect the uplifted Tertiary peneplain. From Koenig the railroad climbs rather rapidly up the steep east slope of the Shawnigan Lake valley to the pass east to the next transverse north-south valley.

52·5 m. 84·5 km. **Malahat**—Altitude 915 ft. (279 m.).

55·5 m. 89·3 km. **17 Mile Post**—Altitude 733 ft. (223 m.). Beyond Strathcona and extending over the

Miles and Kilometres.

summit at Malahat nearly to 17 Mile Post, is the Wark gabbro-diorite gneiss, numerous outcrops of which are seen near the track and on the slopes up to the level of the uplifted Tertiary peneplain. Frequent apophyses of the Colquitz quartz diorite gneiss are also seen, in places so numerous as to form a breccia of the two rocks. From the summit the railroad descends along the west slope of the maturely glaciated, transverse, north-south valley, which has been converted into a fiord, called Saanich inlet. The southern or typical fiord portion, along the side of which is the railroad, is called Finlayson arm. To the south of 17 Mile Post for nearly five miles (8 km.) the road traverses an area of schistose volcanic rocks, cut by two intrusive masses of the Colquitz and Wark gneisses. The volcanics are largely fragmental, of the composition of dacites and andesites, and are interbedded with sedimentary material. They are greatly deformed and their dips are nearly vertical. They have been mapped with the Vancouver volcanics but are interbedded with and transitional into the Leech River slates, which lie to the south and which are probably Palæozoic. At 15 and 14 Mile Posts, canyons, called respectively Arbutus and Niagara canyons, are crossed on high bridges. They are the spillways of hanging valleys. South of the schistose volcanics are the Leech River slates, greatly deformed, contorted and cut by quartz veins. At the bend in the railroad west of Goldstream, the Goldstream river is crossed. Here the Leech River slates are covered by stratified coarse gravels, which constitue the top-set beds of the Colwood delta, built during the recession of one of the Vashon glaciers which occupied Goldstream valley. To the north of the bridge the Colwood gravels are seen resting on the blue Vashon till. From the bridge to Goldstream the railroad follows the profound overthrust fault which separates the Palæozoic Leech River slates from the Eocene Metchosin basalts,

Miles and Kilometres.

which lie to the south. The fault is marked by a wide shear zone, with slickensided walls, some of which may be seen in the cuts south of the track.

61·8 m. 99·5 km. **Goldstream**—Alt. 280 ft. (85 m.). From Goldstream to Colwood, the railroad crosses the terraced Colwood delta. To the north of the track is Langford lake in one of the undrained hollows of the delta, possibly an ice-block hole. To the east of Langford lake is a gravel pit, where the coarse, horizontally bedded top-set beds are well exposed, resting on the finer, cross and steeply bedded fore-set beds. The gravel is used for railroad ballast.

64·6 m. 104·0 km. **Colwood**—Altitude 246 ft. (75 m.). To the east of Colwood, the railroad descends from the delta nearly to sea level, cutting through the Vancouver volcanics, Sutton limestone lentils, and small intrusive masses of Wark gabbro-diorite gneiss and Colquitz quartz-diorite gneiss. To the north of the track, a mile beyond Colwood, is the plant of the Silica Brick Company. Limestone is quarried south of the track, elevated over the track, and burned in down draft kilns. The resulting lime is hydrated and used in the manufacture of sandstone brick, the sand being obtained north of the track from the fore-set beds of the Colwood delta.

66·8 m. 107·5 km. **Parsons Bridge**—Altitude 99 ft. (30 m.). From Parsons Bridge to Victoria, the railroad traverses the southeast lowland of Vancouver island. This portion of the lowland is largely covered by Maywood (inter-glacial) clays with in places a thin mantle of Vashon drift, but with numerous small monadnocks or ledges of the crystalline rocks, Vancouver volcanics, Sutton limestones, and Wark and Colquitz gneisses. Three quarters of a mile east of Parsons Bridge is a limestone lens that has been quarried for flux by the Tyee Copper Company.

68·8 m. 110·7 km. **Esquimalt**—Altitude 35 ft. (11 m.). One half a mile north of Esquimalt the railroad runs

Miles and Kilometres.

along the west shore of Portage inlet, the eastern of the two drowned glaciated valleys which bound the Esquimalt peninsula. Crossing the low "Portage" the railroad runs along the western of the two drowned valleys, Esquimalt harbour. Between Esquimalt and Victoria the railroad crosses the Esquimalt peninsula. Two miles from Esquimalt on the south side of the track is the British Columbia Pottery Company's plant, where in the manufacture of sewer pipe, flower pots, etc., the Maywood clays are mixed with other more refractory clays to bring up the plasticity of the refractory clays. Crossing by a bridge the eastern drowned valley, the outer portion of which is Victoria harbour, the railroad enters the city of Victoria.

72·5 m.
116·7 km. **Victoria**—Altitude 32 ft. (10 m.).

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FIRE CLAY DEPOSITS AT CLAYBURN, B. C.

By

Charles Camsell.

INTRODUCTION.

This excursion has been arranged to start from Vancouver, B.C. going by electric car over the line of the B.C. Electric railway to Clayburn, distant 46 miles (74 km.), for the purpose of examining the brick works and fire clay deposits situated at that point. These fire clay deposits are the most important known in British Columbia, and the fire brick manufactured at the works supply the market for practically the whole province.

The route of the excursion lies eastward from Vancouver, and, crossing Fraser river at New Westminster, continues on the south side of that stream through the level country which forms the delta of the Fraser.

The country embraced within the modern as well as the ancient delta of Fraser river extends from Agassiz westward to the coast, and runs southward into the State of Washington. It is on the whole low and rolling, the elevations ranging from sea level to about 400 feet (122 m.) above. Here and there, however, isolated hills, which attain elevations as high as 1,000 feet (304·8 m.) above the sea, rise above the general level of the plain. The northern boundary of the delta is the Coast range of mountains, whose slopes rise quickly from the delta plain to elevations of 3,000 (914 m.) to 6,000 feet (1,828 m.) above the sea.

The oldest exposed rocks of the region are the granitic rocks of the Coast Range batholith, which border the delta on the north. These rocks have been proved by borings at Vancouver to underlie the Eocene rocks of the delta itself.

Remnants of once more extensive Cretaceous beds occur as hills rising above the general level of the delta in its upper part near Agassiz, and around these the more recent deposits were laid. Sumas mountain, on which the clay deposits are situated is one of those.

Practically the whole of the delta is believed to be floored by stratified rocks of Eocene age, which are referred to in the literature as the Puget group. They consist of only slightly disturbed conglomerates, sandstone, shales and some lignite, laid down in an estuary as delta deposits of the ancient Fraser river. They have an estimated thickness in this region of about 3,000 feet (914 m.), and contain a variety of plant remains from which their age has been determined. This formation contains the fire clay deposits.

Overlying the Eocene beds are unconsolidated deposits, of glacial and post-glacial origin, which were laid down either sub-glacially or at the glacial front during the period of ice recession. These lie at elevations as high as 400 feet (122 m.) above sea level and consist of sands, gravel and boulder clay. They form broad, flat-topped plateaus which were at one time joined together and formed the post-glacial delta of the river. Elevation of the land relative to the sea, however, has taken place since, enabling the river to cut into the older delta so that now only detached remnants of it are to be found. This process of deepening is related to the strong terracing of the upper part of the Fraser valley. The stream is forming a modern delta in the lower part of its course at the present time, and this delta is gradually being pushed seaward into the Gulf of Georgia.

Summary of Geological History of Fraser Delta.

The history of the delta as far as our present knowledge allows us to read it may be summarized as follows:

1. Post-Lower Cretaceous revolution, followed by the development of an estuary, probably by erosion, where the delta of the Fraser river now is.
2. Deposition in the estuary of material derived by erosion from the interior, and carried down by the ancient Fraser river in Eocene times, forming the Eocene delta.
3. Gradual but continuous removal of much Eocene material in succeeding Tertiary times.
4. Glacial period.
5. Formation of Glacial delta by deposition of glacial material during the closing stages of the Glacial period.
6. Post-Glacial uplift resulting in the cutting down and removal of much of the glacial delta deposits.
7. Formation of modern delta at the mouth of the stream.

Miles and Kilometres.

0 m. 0 km. **Vancouver**—Leaving Vancouver on the British Columbia Electric railway to Chilliwack the line runs east through the suburb of Grandview, and then turns southeastward across the peninsula separating Burrard inlet from Fraser river, passing, on the way, through the suburban settlements of Collingwood, Central Park and other places to New Westminster. From Vancouver the line gradually mounts the ridge to the southeast of Vancouver and at Central Park reaches an altitude of 450 feet (137 m.) above sea level. Although this ridge is under-

Collingwood—
Central Park—
Burnaby—

lain by rocks of Eocene age to a depth of several hundred feet no exposures other than those of the Recent and Glacial deposits are visible from the car. These represent the remains of delta deposits laid down in the closing stages of the Glacial period. The summit of the ridge is flat and was at one time heavily forested.

Beyond Central Park, occasional glimpses can be obtained of Fraser river on the right through openings in the trees, and shortly after passing Burnaby the descent to the river is begun.

12 m. 19·3 km. **New Westminster**—The town of New Westminster is one of the older places on the mainland of British Columbia, having been established in 1859. It is situated on Fraser river at tide water, and has deep water connection with the sea. It is built on the slope of a hill facing the south, having the modern delta of Fraser river directly in front and the snow covered volcanic cone of Mt. Baker, 11,000 feet (3,352 m.) in elevation, in the distance to the southeast. At New Westminster the Fraser river is crossed by a steel bridge which affords accommodation for railway as well as vehicular traffic.

Miles and Kilometres.		
12 m. 19 km.	**South Westminster**—	Exposures of fine grained Eocene sandstone showing cross bedding are seen in the railway cuts at South Westminster. Beyond
16·5 m. 26·5 km.	**Kennedy**—	
22 m. 35·4 km.	**Sullivan**—	

this the line gradually ascends the slope of Strawberry hill, until at Kennedy it reaches an altitude of about 300 feet (91 m.), above the sea.

Strawberry hill, like Mount Lehman farther east, is a flat topped plateau covered by unconsolidated sands and gravels representing delta deposits laid down at the close of the Glacial period. They are erosion remnants of the old delta which have not been removed by the post-Glacial deepening of Fraser river.

25·5 m. 41 km.	**Cloverdale**—	Descending the eastern slope of Strawberry hill, the line crosses Serpentine river and enters a low level country which extends along the route of the excursion as far as Jardine. This level country is only a few feet above sea level and is part of the delta built up
29 m. 46·6 km.	**Langley**—	
32 m. 51·5 km.	**Milner**—	
32·5 m. 52·3 km.	**Jardine**—	

by Fraser river in modern times when that stream emptied into Mud bay.

Cloverdale, Langley and other places on this part of the route are the centres of much good agricultural country.

35 m. 56·3 km.	**Sperling**—	At Jardine the line begins to rise again to the top of another of those low plateaus built of sands, gravel and glacial material deposited in the delta of the Glacial period. This plateau is known as Mount Lehman and has an elevation of
37 m. 59·5 km.	**Coghlan**—	
42 m. 66 km.	**Bradner**—	
44 m. 70·8 km.	**Mt. Lehman**—	

about 300 feet (91 m.) above the sea. It is heavily wooded and traversed by a number of sharp deep valleys. Sections of the deposits of which it is built can be seen in a number of places along the line of travel.

Miles and Kilometres.

46·5 m. 74·8 km. **Gifford**— 49 m. 78·8 km. **Clayburn**— Descending the eastern slope of Mount Lehman near Gifford, the line is only a short distance from Fraser river, which can be seen on the left. Here again is low flat open country only about 20 feet (6 m.) above sea level. The railway runs for about five miles (8 km.) through this country to Clayburn station which is about one mile distant from the brick works of the Clayburn Brick Company.

From the brick works a narrow gauge railway runs up the valley of Kelly creek into Sumas mountain for a distance of about $3\frac{1}{2}$ miles (5·6 km.), to the fire clay deposits. The railway is used for carrying the clay from the mines to the brick works and is operated solely for the convenience of the Clayburn Brick Company.

GEOLOGY OF THE REGION ABOUT CLAYBURN.

GENERAL DESCRIPTION.

The village of Clayburn, populated almost entirely by people employed in the mines and brick works, is situated on the western edge of Sumas mountain, about a mile from the station. Sumas mountain itself is a heavily wooded hill rising through the flat lying delta country to an altitude of about 1,000 feet (305 m.) above sea level. The central part of the mountain is made up of massive quartz porphyries which are believed to be of Lower Cretaceous age, and around this has been deposited a series of beds of Eocene age consisting of conglomerate, sandstone, shale and thin seams of coal. The Eocene beds rest unconformably on the quartz porpyhry floor, and have a gentle dip ranging from 5 to 15 degrees to the southwest. Outcrops of these rocks are rare, and on the lower slopes of the mountain they are covered by Pleistocene sands and clays.

The Eocene deposits contain the beds of fire clay which are said to be the most important on the Pacific Coast of Canada.

About 1,000 feet (305 m.) up Kelly creek from the brick works is situated a bank of clay from which material is obtained for manufacture into common brick. The section in the bank shows a bed of sand separating two beds of clay, over which is about 15 feet of river gravels. The beds are all of glacial or post-glacial origin and not firmly consolidated, so that they can be worked by a steam shovel.

Two miles (3.2 km.) beyond these clay deposits is the Thornton mine, the first mine at which the Eocene shales are worked. These beds outcrop on either side of the creek and consist of shales overlaid by conglomerate and underlaid by sandstone. The beds are of Eocene age and dip about 6 degrees to the southwest. The shale is separable into two beds which are described by Dr. H. Ries (**4**, p. 390) as "a lower grey shale of smooth plastic character, and an upper purplish one which is harder and grittier. The former is buff-burning, and on the south side of the track is at least 6 feet (1.8 m.) thick, while the upper or grey burning shale is 4 (1.2 m.) to 6 (1.8 m.) feet thick." A test of the lower shale by Dr. Ries showed it to be of good plasticity, burning to a good buff pressed brick.

A mile beyond the Thornton mine and on the opposite slope of the mountain is what is known as the fire clay mine. This was formerly worked as a coal mine and contains a seam of coal up to 3 feet (.9 m.) in thickness. The section at this mine as measured by Dr. Ries is as follows:

Sandstone....................	
Upper fire clay.................	8 ft.—2.4 m.
Coal with flint clay partings.....	6 in. to 1 ft.—.15 to .3m.
Lower fire clay.................	7 ft.—2.1 m.
Ferruginous clay...............	4 ft.—1.2 m.
China clay.....................	10 to 15 ft.—3 to 4.5m.

Only the portion between the coal seam and the china clay is at present being mined, a selected sample of which fused Cone 32. The china clay is a fine grained whitish clay fusing at Cone 22. It is not being mined.

INDUSTRIAL NOTES.

The shales of the Thornton and fire clay mines are mined underground by pillar and stall methods, and an output of about 100 tons per day is maintained.

The capacity of the brick works is about 80,000 bricks per day, and the product of the kilns includes common, pressed and fire brick, drain tile and sewer pipe, and various other fire clay products.

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VICTORIA, BRITISH COLUMBIA, TO CALGARY, ALBERTA.

The east bound portion of C 1 Excursion follows as far as Calgary, the same route as that taken in the westward journey, the guide to which is given on pages 105 to 274 of Guide Book No. 8, Part II.

CALGARY TO WINNIPEG.

Via Canadian Northern Railway.

BY

A. MACLEAN.

INTRODUCTION.

At Calgary the excursion leaves the main line of the Canadian Pacific railway, and runs as far as Winnipeg

over the lines of the Canadian Northern railway, following a route considerably north of that traversed in the westbound journey.

This route lies towards the northern fringe of the prairie portion of the Great Plains area, through a region whose main geologic and physiographic features are similar to those obtaining in the southern part of the same region, a description of which is given on pages 77 to 99 Guide Book No. 8.

The points of interest to be seen on this portion of the excursion include: Dinosaurian bone beds at Munson, Alberta; Foraminiferal Cretaceous limestone and the beaches of glacial Lake Agassiz at Pine River, and the fossiliferous Devonian on Lake Winnipegosis, where the fauna is of a distinctly European type.

ANNOTATED GUIDE

(Calgary to Munson.)

Calgary—Altitude 3,425 ft. (1,044 m.). From Calgary the route of the excursion lies northeastward over an open rolling prairie country to Munson which is situated on a tributary of Red Deer river.

Munson—Altitude 2,600 ft. (780 m.). Here a short excursion is made to points along Red Deer river, where beds of the Edmonton formation, containing Dinosaurian remains, are exposed.

THE EDMONTON FORMATION ON RED DEER RIVER NEAR MUNSON, ALTA.

The distance from Munson to the Red Deer along the shortest route is about six and a half miles (10.5 km.) This route is directly west along the road running in an east and west direction through the town.

Owing to the proximity to Fox coulee and the Red Deer valley, the road crosses several tributary coulees on its way to the river. After crossing the first of these just outside the town, one reaches a summit from which the land slopes very gently to the banks of the Red Deer.

From this summit may be seen several of the prominent physiographic features of the region.

To the east, about 18 miles (29 km.) beyond Munson, rises the Hand Hills ridge—the most marked of all the hills to be seen from here. To the southwest of this on the other side of Red Deer valley, are the Wintering Hills, while in front—to the north and west—are the Three Hills, and still nearer Sarcee Butte. To the immediate west is the valley of the Red Deer river, and to the south and west across this valley is the rough and broken country about the Knee Hill creek, which stream flows into the Red Deer river, at a point about directly southwest of Munson.

Near Munson the subsoil is very heavy, giving the heavy waxy "gumbo" soil of the western plains, but on the last facet of the upper slope before reaching the edge of the cut banks, the soil becomes lighter and contains more sand. Both types of soil, however, have given excellent results during the period they have been cultivated.

At a point four miles (6·4 km.) to the west of Munson, one may continue for two and a half miles (4 km.) farther west and come directly to the edge of the cut banks, or turn to the south and so get a road along a fairly good grade to the river flats either at the Wigmore ferry or at the Wigmore ford—opposite the mouth of the Three Hill creek. To reach this latter place the road turns again to the west at a point one and a half miles (2·4 km.) south of the last road intersection, and finally follows a private trail down to the river flats, and then along these in front of the Edmonton exposures.

In passing down to the river flats, and in driving along them, there are several excellent examples of the different stages of denudation and erosion. On either side of the river valley several coulees and ravines have cut their sharp "V" valleys back into the table land above. Just across the river the Three Hill creek, having cut its channel down to the present base level of its mouth, has subsequently widened its valley to have a fairly extensive flat at the bottom. On the nearer (northeast) side of the river, among the Bad Land features, are many cases where the valleys in heading back from the river, have encroached on each other and have cut off one or more buttes from the table land behind. In other cases these have been worn from the flat-topped buttes to sharp ridges or conical hills, which finally pass to low rounded hummocks in the last

stages of denudation possible with the present river level.

As seen from below, the cut banks of the river and coulees and the sides of the buttes show the typical exposures of the Edmonton series. From the level of the river flats below to the grassy slope above, the light and dark coloured banks or beds are so marked and so characteristic that even from a distance of some miles one has no difficulty in detecting them and recognizing them as belonging in all probability to this formation. On close examination it is seen that the light coloured bands are greenish or yellowish gray in colour, and consist of sandstone, shale or clay, with the clay predominating.

The dark coloured bands are red or black in colour, the red bands being often similar in composition to the gray, with the exception that they have a much higher ferric iron content. In some cases this iron has been concentrated in several bands of ironstone concretions. These bands are in general from four to six inches (10 to 15 cm.) in thickness, and are distributed at various levels in different places. On the weathered bank they project from the slope for a few inches, until the nodules of which they are composed are undermined, and of their own weight fall to the bottom of the bank.

The black bands are either of a dark shale, or mark the outcroppings of different seams of coal which may be as many as six in number, although this number is not constant, since these beds are not always continuous for great distances. The smallest of these coal seams at this place is about six inches (15 cm.) in thickness, and the largest about three feet (1m.).

As exposed at the surface the coal is of poor quality, being lignitic in character. It crumbles and disintegrates rapidly on exposure to the changes of the atmosphere, but when freshly mined or when exposed under water, the quality is much better and has a wide local use. In many instances it is simply quarried or mined out of the nearest exposure by the farmers themselves, but in addition to this there are several mines which supply the towns and such of the farmers who care to buy at the pit mouth.

It is within one of these seams that the greatest amount of fossil wood is preserved. Stumps, tree trunks, and large slabs of "wood" may be found lying along the river flats near the place where they have weathered out of the coal seam.

Many of the remains are more or less silicified, and in some cases are opalized. In most cases, the structure is excellently preserved, the fossil wood being so like the modern that in many cases it is easily mistaken for a piece of recently weathered wood.

The vertebrate remains occur at a higher level, some 60 or 70 feet (18 or 21 m.) below the top of the bank. The bed containing them, varies from a yellow clay or shale to a fairly compact gray sandstone, and the state of preservation differs with the material of the bed in which it is found. Some excellently preserved specimens are found in association with the concretionary iron beds, but in these cases, it is almost impossible to separate the iron from the bone.

Owing to the fact that most of the exposures are on the steep face of the cut bank, it is sometimes difficult to find the complete set of bones in place. As the bank is eroded, some of the bones become undermined and roll to the bottom of the slope, where they lie until completely broken up by exposure. By tracing these fragments up the bank, some may be found projecting a few inches from the surface. To extract them from this bed means that a large amount of overburden has to be removed, or that the bones should be taken out by "mining".

Most of the specimens found here are reptilian, of the order Dinosaurs [**6** and **7**], although farther down the river there are reported remains of fishes and small mammals. None of these have as yet been found in this region.

The exact position of this fossil-bearing bed is often difficult to determine, owing to the tendency of the bank to break and slide to the lower levels. On these slips, erosion is often more effective than on the undisturbed levels above, so that, in some cases, the bone-bearing beds have been exposed by the butte weathering down to its level. In such cases, the task of collecting is comparatively easy.

The slipping of the banks mentioned before is in this formation even more prevalent than in other regions where clay forms the greater part of the subsoil. The tendency to slip is increased by the presence of a varying amount of "bentonite" disseminated through the whole formation, and sometimes aggregated in beds of considerable thickness. This material when moist, is very waxy or soapy, and when given sufficient amount of water has a tendency to become very gelatinous and to expand excessively. The presence of

bentonite in the subsoil is probably in part the cause of the waxy nature of the "gumbo" soil, and is also responsible for a great many of the engineering problems, where difficulty is experienced in holding a road bed on the side of a cut, or even in maintaining the grade over a level prairie underlain by it.

Throughout this part of this formation there is a distinct lack of continuity in the beds. In some exposures there may be shown a regular succession of beds of clay with no sandstone apparent, while a short distance away distinct hard beds of consolidated sandstone are found interbedded with shale and clay. In some cases, the clay passes imperceptibly into the sandstone, and in other cases gradually pinches out into a thin lens, while above it the sandstone comes in again in the same manner.

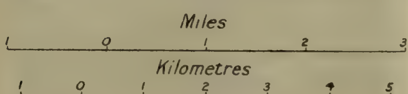
On this account it is difficult to give a section which is applicable without modification throughout the whole region, but the following section as worked out by J. B. Tyrrell may be considered as fairly characteristic of the Edmonton formation in this region. [**3**].

		ft.	in.
3·0 m.	Light coloured boulder clay, including many Laurentian boulders and pebbles—at least	10	
6·0 m.	Whitish, clayey sandstone..................	20	
3·6 m.	Grey, carbonaceous shale..................	12	
·7 m.	Coal (burnt out)..........................	2	4
4·5 m.	Whitish, clayey sandstone.................	15	
·7 m.	Coal (brown lignite)......................	2	3
7·5 m.	Light grey sandy shale with 6″ band of ironstone near top..........................	25	
1·8 m.	Yellow, sandy shale.......................	6	
0·6 m.	Shale, mixed with coal....................	2	
18·0 m.	Grey, readily weathering sandstone, with irregular masses of ironstone and reptilian bones...............................	60	
1·5 m.	Lighter grey sandstone....................	5	
0·3 m.	Sandstone and ironstone...................	1	
7·5 m.	Light grey, rather hard, sandy shale, with irregular bands of ironstone............	25	
·15 m.	Nodules of flinty ironstone, with impressions of plants............................	0	6
3·0 m.	Light sandy shale.........................	10	0
0·75 m.	Hard ferruginous sandstone, containing obscure plant impressions...............	2	6
1·8 m.	Light grey sandy shale....................	6	0
·3 m.	Rather hard lamellar sandstone.............	1	0
33·0 m.	Light grey shaly sandstone, containing especially in the lower portion, more or less irregular bands of ironstone nodules......	110	0
94·68 metres.		315	7

C3.

Geological Survey, Canada

Red Deer Valley in the vicinity of **Munson** and **Drumheller**



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9

ANNOTATED GUIDE.

MUNSON TO DAUPHIN VIA SASKATOON.

Miles and Kilometres. from Saskatoon.

The route traversed between Munson, Alberta, and Dauphin, Manitoba, is over hilly and rolling prairie underlain by Cretaceous rocks. The first section between Munson and Saskatoon is mostly prairie, while the country to the east of Saskatoon as far as Grandview is fairly well wooded. Just west of Dauphin the railway cuts through the first prairie escarpment between the Riding and Duck mountains.

The country is underlain by the Edmonton series [**3** and **4**] as far east as Richdale, then succeeded in descending order by the Fort Pierre shales which extend east to Grandview. From this point nearly to Dauphin, the country is underlain by the Niobrara shales and marls succeeded at Dauphin by the Dakota series.

Munson—Altitude 2,600 ft. (780 m.). Just west of the station a cutting in a coulee shows about six feet (1·8 m.) of stratified sand which is not consolidated to a consistent stone. Overlying it is a hard band of sandstone exceedingly rich in fossils (Ostrea). This band is about eight inches (20 cm.) in thickness, and probably owes its consistency to the presence of cementing material from the shells which form the greater proportion of the bed.

From mile posts 166-167 to the river, both sides are denuded to show typical exposures of the Edmonton formation, and the railroad enters the lower river flats at mile post 170·5.

Munson Junction—Altitude 2,604 ft. (781 m.). The Hand hills to the east rise about 1,000 feet (303 m.) above the general level of the prairie and form the most marked physiographic feature of this region. They have received their name from the resemblance which their outline bears to an outstretched hand, four or five ridges or "fingers" to the south radiating from a broader elevation, "the palm", to the north. The Indian name *Michichi*

Miles and Kilometres.

ispatinan referred to this resemblance and the idea has been retained in the English appelation —the Hand hills.

The lowest exposures of these hills show rock of the Edmonton series. Above this may be seen in some places, the brownish sandstone of the Paskapoo series, while the summit of the hills is covered with beds of Miocene age. These beds are about 270 feet (81 m.) in thickness, and this exposure is the only one of any extent in this region.

245 m. 374 km. **Richdale**—Altitude 2,587 ft. (776 m.). To the west of Richdale the country is comparatively flat and the soil heavy and rather impervious, so much so that sloughs are common, and deposits of alkali are more prevalent than farther east, where the land is comparatively dry and the soil not excessively heavy. The crossing of Berry creek near Richdale marks the boundary between the Edmonton series to the west and the underlying Fort Pierre shales to the east.

Youngstown—Altitude 2,434 ft. (730 m.). East of Youngstown toward Benton, the hills form a ridge extending in a northeasterly direction. The surface generally varies from irregular to gently rolling with an almost complete absence of tree and scrub.

106 m. 170·5 km. **Brock**—Through Brock and Darcy the ridges tend northeasterly. The cuttings show deposits of gravel and glacial till heavily charged with boulders.

78 m. 125·5 km. **Ridpath**—West of Ridpath the railway skirts the Bad hills, and the country in consequence is somewhat rougher. Eastwards to Delisle the country is typical flat prairie, becoming more rolling on approaching Delisle and passing into a zone of hilly country to the west of Vanscoy.

505 m. 812·7 km. from Winnipeg. **Saskatoon**—Altitude 1,655 ft. (500 m.). Saskatoon lies in one of the great wheat growing centres of Western Canada, and is situated on the bottom lands of glacial Lake Saskatchewan, the eastern border of which lies about 30 miles

Miles and Kilometres. (48 km.) to the east of the city. Neither the area nor the shore line of the lake has as yet been worked out in any detail.

278·7 m. 448·4 km. **Kamsack**—Kamsack marks the crossing of the broad valley of the Assiniboine. The divide between the Assiniboine basin and the river flowing into Lake Dauphin is reached at Shortdale. The wind gap at this point is a result of the piracy of the Valley river.

207·4 m. 333·7 km. **Grandview**—Grandview marks the upper limits of glacial Lake Agassiz. From there to Gilbert Plains the railway crosses the delta deposits formed during the highest stage of the lake.

189·4 m. 304·8 km. **Ashville**—Ashville is situated on a well marked beach of glacial Lake Agassiz. Delta deposits of a later date than the above extend from Gilbert Plains to Dauphin. The cuts along Valley river show exposures of the Niobrara formation.

177·8 m. 286·1 km. **Dauphin**—Altitude 957 ft. (287 m.).

ANNOTATED GUIDE.

DAUPHIN TO ETHELBERT AND PINE RIVER.

177·8 m. 286·1 km. **Dauphin**—Altitude 957 ft. (287 m.). Dauphin is a junction point on the line of the Canadian Northern railway from which subsidiary excursions run northward to Pine River and Lake Winnipegosis. The object of the excursion to Pine River is to examine forameniferal Cretaceous limestone, and at the same time to view beaches of glacial Lake Agassiz which are here excellently preserved. At Lake Winnipegosis, Devonian rocks are exposed which in places contain *Stringocephalus burtoni*, a fossil common in the Devonian of Eurpoe, but only found in America in this locality and in the valley of Mackenzie river.

196 m. 313·6 km. **Sifton Junction**—Altitude 959 ft. (287·7 m.). From Sifton Junction the road takes a northwesterly course as far as Ethelbert, at which

Miles and Kilometres.

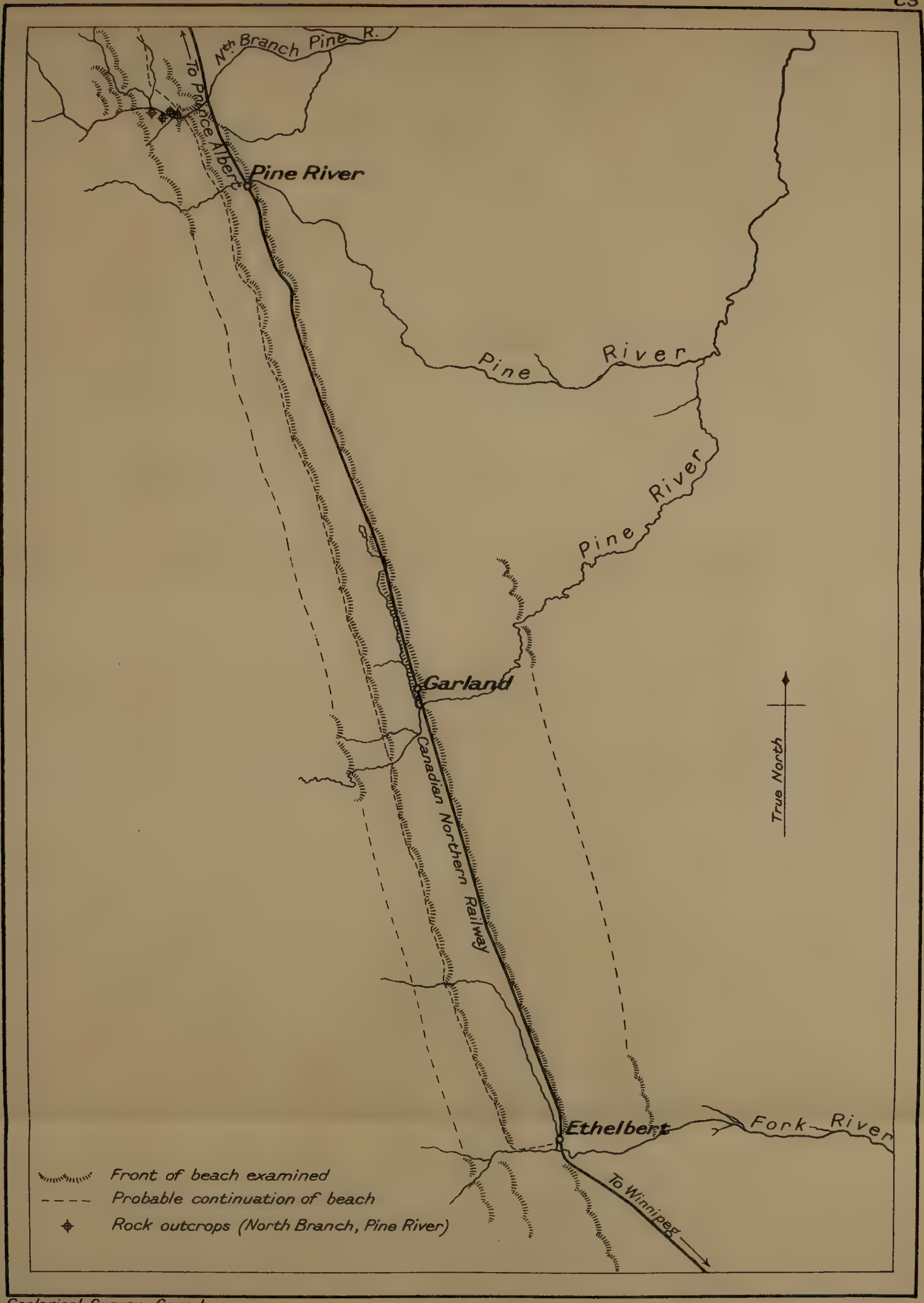
place it turns to the north-northwest, and continues this direction through Gasland, Pine River, Sclater and Cowan. Beyond Cowan the road turns to the west, following approximately the contour line in front of Duck mountain. This line is here deflected toward the west as a result of the break in the escarpment face caused by the valley of Swan river.

210 m. 336 km. **Ethelbert**—Altitude 1,126 ft. (338 m.). Between Sifton Junction and Ethelbert, the road gradually ascends the old bed of Lake Agassiz toward the western shore line. In this distance it doubtless crosses a number of the later shore lines of the lake formed during its recession, but in this region they are obscure and not easily recognized.

The first distinctly marked beach along this line is reached at Ethelbert, just after the road crosses Fork river and enters the town. The elevation here is 1,126 feet (337 m.), so that this shore line is 167 feet (50 m.) above the lake bottom at Sifton. At this same elevation this beach continues south for about 25 miles (40 km.), to a point about west of Dauphin. It stands out as a distinctly marked ridge, and forms the location for a government colonization road. At Ethelbert, this road turns to the west for a mile, and then follows another of the beaches which will be mentioned later, while this beach is occupied by the railroad between Ethelbert and Pine River.

At Ethelbert an opportunity is afforded to observe the relation of the beach to the surrounding country. The railway is here located on the summit of the beach, while the main street of the village is on its eastern flank. An examination of the ditches and excavations along this shore line shows distinctly the sands and gravels of a shore deposit.

About one mile (1·6 km), to the north of the town a road running toward the east shows very good sections of other lower beaches. The first is about 300 yards, (270 m.), to the east of the track, and the second about a mile



Geological Survey, Canada.

Old Beaches, Ethelbert to Pine River

Miles

Kilometres

Miles and Kilometres.

and a half (2·4 km.) east of the railroad. The first is not very distinct, but the second is fairly well marked, and seems to be continued toward the north. In both these instances, the beaches are distinguished rather by their content than by any marked ridge or terrace effect, although this also is to be noticed by careful examination and observation.

On returning to Ethelbert and crossing that beach toward the west, there is evident a feature which is often to be noticed along these lines, that is, that the ground immediately behind and to the west of the beach is lower than the summit of the beach itself. As the general drainage of the district is toward the east, this results in a stretch of marshy land to the west or upper side of the old beach. In other cases the streams from the west, being deflected by this barrier, flow along parallel to the beach until they reach a gap which has been cut through the old shore line. In this manner the ground to the west is cut still lower, and the ridge appearance of the beach is accentuated.

One of these streams, a branch of Fork river, is to be noticed as soon as the Ethelbert ridge is crossed. Beyond the valley of this stream, the land rises slowly toward the west for about a mile (1·6 km.), till another and larger beach is met. This beach rises to a height of about 40 feet (12 m.) above the summit of railroad at Ethelbert. Throughout its length this beach is larger and better marked than the one to the south along which the railroad runs. Like that one also, the ridge—locally termed "the big ridge"—drops off sharply on the western side to the valley of another branch of Fork river. On the eastern flank the government colonization road previously mentioned, continues northward.

One mile (1·6 km.) farther to the west is another beach. Like those to the east of Ethelbert, however, this beach is also marked by a gravel bed of apparent shore origin rather than by a distinct change in elevation. The

Miles and Kilometres.

beach corresponding to this is better marked at Pine River, and may be observed there.

219 m. 350·4 km. **Garland**—Altitude 1,127 ft. (358 m.). From Ethelbert to Garland, the railroad as has been before mentioned, follows the lower of the two most distinct beaches. This beach with practically no grading, forms the road bed with the exception of a few places, where streams have broken through the ridge, and so have necessitated filling and bridging.

At Garland, an irregular trail runs to the east toward Winnipegosis. This road crosses three of the old beaches in four miles (6·4 km.) but as the country is bush covered the relative elevations of the ridges are concealed. The prevalence of Banksian pine and the light dry soil underfoot readily call attention to them, however, and subsequent examination reveals them as well marked beaches.

229 m. 366·4 km. **Pine River**—Altitude 1,146 ft. (344 m.). At Pine River a better opportunity is afforded of leaving the lower ridge, and again observing 'the big ridge' to the west, which is distant from the railroad about three quarters of a mile (1·2 km.) A rather poor trail leads across the wet heavy soil commonly found between the ridges, but when the ridge is reached, a good trail runs along it to the north. In following this trail for a mile or two in this direction, the shore line features are especially well shown.

At about 1·3 miles (2·1 km.) north of Pine River station, both ridges are cut through by North Pine river. South of this, the lower ridge had been gradually approaching 'the big ridge,' and after this interruption, has apparently lost its identity in the side of the more western one, which continues north of the river more marked than before.

After crossing the river, the main trail continues to follow the ridge, skirting the bank of the river for some distance. About one mile from the river crossing, this trail branches, the main branch continuing along the ridge

Miles and Kilometres.

and a minor trail following up the course of the river. On this trail, at about two miles (3·2 km.) from the place where the main trail crosses the river, are to be seen a series of three beaches. These succeed each other at short intervals, are very well marked, and as in many other instances are covered with Banksian pine.

Along the North Pine river are several exposures of Cretaceous rocks. A short distance above the point where the main trail crosses it, the river cuts into "the big ridge". At the base of this cutting, about 12 feet (3.6 m.) of shale is to be seen. This shale is for the most part of a dark gray colour and thin bedded, and weathers to thin flakes which rapidly disintegrate to mud. About seven feet (2.1 m.) above the water level is a thin bed of yellowish white clay, soft in texture, and having a peculiar astringent taste.

A short distance up the river and on the same side — the north—is another similar exposure. Both of these are probably of the Benton series. [**4**].

About three quarters of a mile (1.2 km.) farther up the river are two cliffs on the opposite or south shore of the river giving very good exposures of the Niobrara shales [**4**] and limestones. The shales are of a lighter colour than those of the Benton below, and the limestone might better be described as marl or at least calcareous shale. It is very rich in foraminifera, Globigerina especially being present in large numbers. In addition to these, other and larger fossils are to be found in considerable quantity. Of these, a species of Inoceramus and a large species of Ostrea are particularly abundant. [**5**, p. 102].

DAUPHIN TO WINNIPEGOSIS.

Miles and Kilometres from Winnipeg.

177·8 m. 286·1 km. **Dauphin**—Altitude 957 ft. (287 m.).

195·5 m 312·8 km. **Sifton Junction**—Altitude 959 ft. (287 m.). Sifton Junction almost overlies the contact of the Cretaceous and Devonian, and from this point to Winnipegosis the road is over the latter rock although as before no exposures are to be seen along the line of railway.

The railway here passes through a flat, wooded country which is now being opened to settlers. Through the clearings made by them occasional glimpses may be had of the escarpment to the west.

200·5 m. 320·8 km. **Fishing River**—On this branch railway two stations are passed—one at Fishing River and the other at Fork River. At these places two streams of the same names respectively cross the railway and empty into Mossy river, which stream drains Lake Dauphin and empties into Lake Winnipegosis about one half mile (·8 km.) north of Winnipegosis station.

207·6 m. 332·1 km. **Fork River**—Altitude 872 ft. (261 m.)

From Sifton north to Winnipegosis, the country is mostly settled by Ruthenians who still retain in the architecture of their churches and houses and in their methods of farming many of the ideas which they brought with them across the sea. In addition to these are a number of Icelanders settled in and around the town, and during the summer a few Indians usually move down from the Pine Creek reserve and pitch their camps near the village.

218 m. 340·8 km. **Winnipegosis**—Altitude 839 ft. (251 m.)

A lumber mill is in operation near the mouth of Mossy river, but the principal industry of the town is fishing. Some years ago this was prosecuted throughout the year, but latterly it has

Miles and Kilometres.

been restricted to the winter season, when the fish must be caught from under the ice. By means of horse and dog teams communication is maintained between the fishing stations and the village in winter, while in summer, the lake is navigated by gasoline launches, steam tugs and sailboats.

THE DEVONIAN OF SNAKE ISLAND AND SOUTH SHORE OF LAKE WINNIPEGOSIS.

The southern end of Lake Winnipegosis is underlain by the Manitoban formation of the Upper Devonian. The grey limestones of this formation are best seen at Snake island about four miles (6·4 km.) east of the town of Winnipegosis and the mouth of the Mossy river. On the south end of the island is located the Government fish hatchery. This and the buildings connected with it are the only structures erected there.

The island is about a mile (1·6 km.) in length. It is very irregular in shape, the two ends being about one half mile (0·8 km.) in width, while the isthmus which joins them is often but 50 feet (15 m.) in width. This irregular shape is probably due to the manner in which the rock outcrops at different places on the island and to the direction of the prevailing winds of the lake.

The long axis of the island lies in a direction about northeast and southwest. The outcrops all occur on the northwestern face of this axis. Three of these—two on the north end and one on the south—stand from 15 to 20 feet (4·5 to 6 m.) above the lake. In the lee of these elevations, sheltered from the prevailing west and north winds, the island has been gradually extended toward the south and east by continued marshy growths. At the middle of the island, where the rock barely comes above the surface of the lake, this protecting influence is lacking. Here only such marsh has been formed as has been able to creep in with the aid of the shelter given by the larger trees which have grown on the expansions at the ends of the islands.

The shore on the northwestern face shows no such marshy growths. The strong winds blowing from this direction tend to prevent marshy vegetation gaining a foothold on this side, while the heavy ice shoves of the

spring season serve to effectually scour out the shore and so maintain a clean gravel beach along the front. The effect of these ice shoves may be seen in the movement of some of the large boulders which lie thickly scattered along the shore, and in the long parallel ridges of non-assorted gravel which build up the beach some feet above the marshy ground beyond and behind it. These ridges may be further worked over by the waves which serve sometimes to intensify and sometimes to lessen the effect produced by the ice shove.

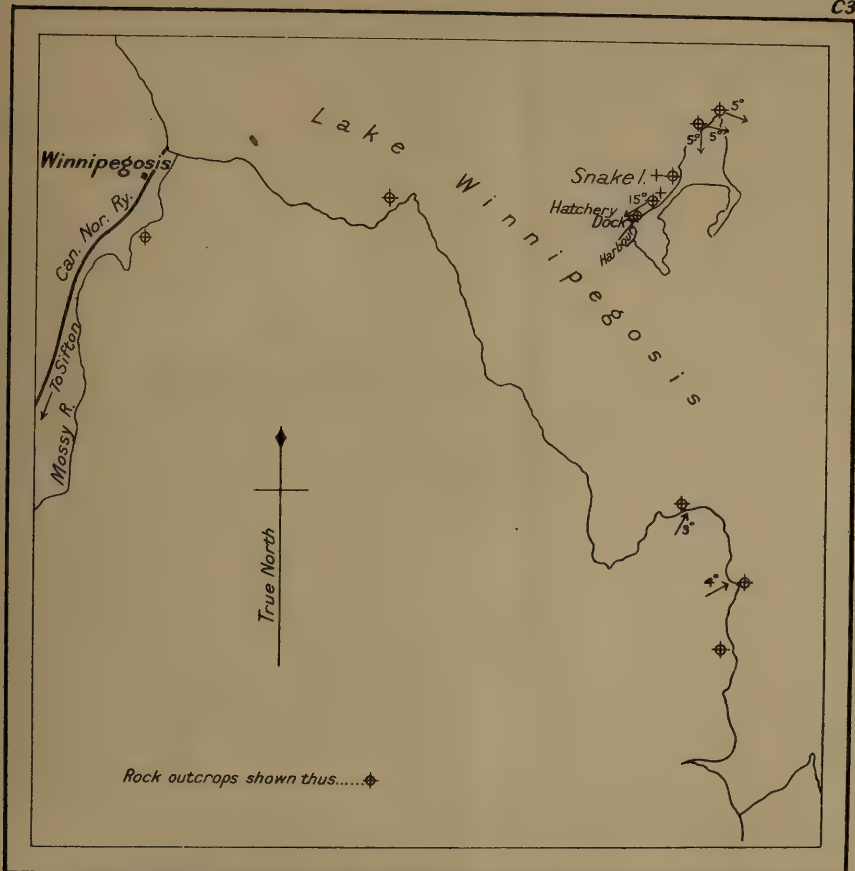
As already indicated the rock outcrops are five in number: two at the north end; two on the isthmus; and one on the southern expansion.

In the three exposures which stand high enough to show the dip, there is a marked inclination of the beds, varying from 5° to 15° in direction from S. 85° E. to S. 45° W. The dip in each case, however, seems to be quite local, and does not serve to bring any new beds to the surface, for in all five outcroppings the rock seems quite similar, and it is probable that there is no bed exposed on the island that is not represented in the higher of the two cliffs at the north end.

The first exposure at this end forms the northwest corner of the island, and extends for about 200 feet (60 m.) along the northeast shore, and about 300 feet (91 m.) along the the northwest shore. The dip, from 4 to 5 degrees is fairly constant in a direction about S. 80° E. to S. 70° E. This causes the beds to dip down to the shore and under the water on the northeastern side, and brings them out in a cliff on the northwestern. From the summit of this cliff, the beds gradually break away toward the southwest till they are lost under the drift and gravel of the beach.

At its highest point the cliff stands 12 or 13 feet (3·6 m.) above the water. It consists of three fairly well marked divisions. The lower four feet (1·2 m.) is a fine grained, fairly brittle limestone, light in colour and bearing a few fossils. Above this is a coarse, dark bed of limestone, very fossiliferous and from 12 inches to 15 inches (30 cm to 38 cm.) thick. A weathered section of this shows innumerable sections of brachiopod and other shells. The upper surface of this bed displays fragments of shells in all conditions of mechanical disintegration. This comminution together with wave marks shown on one of the blocks

C3.



Geological Survey Canada.

Snake Island and **South Shore** of **Lake Winnipegosis**

Miles

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1 0 1 2 3 4 5

from this level, would indicate that this bed at least was formed at a depth within the limits of wave action.

In some places the succeeding beds are separated from this by a thin layer of shale 0·4 inches (1·cm.) thick. These upper beds are similar to the lower five feet, but are darker, not quite so fine grained, and are perhaps more fossiliferous.

They are seen to better advantage in the next exposure to the southwest, where a cliff about 20 feet (6 m.) above lake level shows a total thickness of 12 or 13 feet (3·6 or 4 m) above the fifteen inch (38 cm.) fossiliferous bed previously mentioned. In a bed at the summit of the cliff, 11 feet (3·3 m.) above this middle layer, are shown some of the star shaped sponge spicules.

Astreospongia hamiltonensis occurs abundantly in a single bed of the limestone.

Other fossils which have been collected here include the following:—*Cyathophyllum vermiculare* var. *praecursor*, *Alveolites vallorum*, *Atrypa reticularis*, *Atrypa spinosa*, *Cyrtina hamiltonensis*, *Paracyclas elliptica*, *Raphistoma tyrrellii*, *Bellerophon pelops*, *Euomphalus subtrigonalis*, *Omphalocirrus manitobensis*, *Hyolithes alatus*, *Gomphoceras manitobensis*, *Cyrtoceras occidentale*.

The cliff mentioned appears, as seen from the lake, to be a section across an anticline. On closer examination, it appears to be a section through a dome some distance beyond the centre. The apparent dips along the face, which at either end bring the beds up from the shore level, are but the components in this plane of the angles of dip which would radiate from the centre of the dome.

Below this cliff a great many of the blocks are from the middle highly fossiliferous bed, which appears more resistant than the other beds. On one of these blocks are shown distinct curved wave marks, three crests and three hollows, the distance from crest to crest being about 18 inches (45 cm.) and the depth of the hollow below the crest about four inches (10 cm.).

Farther to the south flat lying exposures are shown, one at each end of the isthmus. They appear to be horizontal and probably represent beds near the middle of the cliff before mentioned.

On the southern end of the island, just at the hatchery dock, is the last rock outcrop. This dips comparatively sharply towards the southwest, the angle of inclination varying from 15 degrees to 30 degrees. In all a total

thickness of about 12 feet (3·6 m.) is exposed. These beds seem to be similar to those shown in the upper half of the 16 foot (4·8 m.) cliff on the north end of the island.

Other outcrops of the rocks here described are to be seen on the south shore of Lake Winnipegosis adjacent to the island. As may be noticed on the map one of these is directly west, and the others directly south of the south end of the island.

None of these exposures exhibit any features not shown at that place, with the exception perhaps of those immediately south which may contain more fish remains than the outcrops on Snake island. These remains are probably of *Dinichthys canadensis* mentioned by Tyrrell in his report on the island. [**4** p. 163.]

The vicinity of Winnipegosis and Snake island is particularly interesting from the standpoint of the development of the knowledge of Western geology for "It was here that Prof. H.Y. Hind [**1.**] in 1858 made the collection of fossils which first determined the existence of Devonian in Manitoba." [**4** p. 163]. In the same year a report was made on the occurrence of rock on the island by A. W. Wells [**2.**]. In the summer of 1889, the island was visited and reported on by Tyrrell [**4.**], from whose report the references just cited have been taken.

THE DEVONIAN OF DAWSON BAY, LAKE WINNIPEGOSIS.[a]

Dawson bay is a large pocket-like expansion extending west and south from the northern end of Lake Winnipegosis. This bay is excavated wholly in Devonian rocks and the numerous exposures on its islands and shores and along Red Deer river show the whole of the Devonian section so far as it is known. This makes Dawson bay the most favourable region in which to study the Devonian section of Manitoba.

A spur leaving the main line of the Canadian Northern at Mafeking reaches the bay at the mouth of Steep Rock river. From this point the localities to be mentioned will be reached by gasoline launches.

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a This excursion is contingent on the completion of the branch railway from afeking to the mouth of Steep Rock river.

The basal beds of the Devonian, which rest upon Silurian limestones northeast of the entrance to Dawson bay, are not known to be exposed about the north end of Lake Winnipegosis. The Devonian section of this region includes two formations, the lower is a dolomitic limestone, estimated to be 200 feet (60 m.) thick, called the *Winnipegosan* of middle Devonian age. The upper formation is chiefly a non-magnesian limestone, but it includes some shale, and has a thickness of about 210 feet (64 m.). The younger Devonian formation has been called the *Manitoban*. The lower Devonian appears to be absent from this region. The sharp dips of 5 to 20 degrees seen at some localities have only local significance. The general dip of the rocks of this region is westerly and amounts to probably not more than 40 feet (12 m.) per mile.

It follows, therefore, that the outcrops showing only the lower formation of the Devonian lie mainly on the eastern side of the bay.

A typical exposure of the Winnipegosan dolomite is shown in the cliff at Whiteaves point 10 miles (16 km.) east of the mouth of Steep Rock river. Whiteaves point is a cliff of white compact dolomite with a maximum height of 31 feet (9·4 m.) above the water, and extends a mile along the shore. Beautifully preserved fossils occur in abundance in this dolomite. Among the common and characteristic forms are *Stringocephalus burtoni* and *Gyroceras canadense*. The first named species, although a familiar middle Devonian fossil in Europe, is known in America only in the Devonian of Manitoba and Mackenzie River valley. It is nearly everywhere a common fossil in the Winnipegosan dolomite, but does not range upward into the Manitoban formation. Another excellent exposure of the *Stringocephalus* dolomite occurs at Salt point four miles (6·4 km.) west of Whiteaves point. About 30 feet (9 m.) of white dolomite, weathering yellowish, are exposed in the cliff here. The fauna includes a considerable number of species, among which may be noted *Sphaerospongia terssellata*, *Columnaria disjuncta*, *Atrypa reticularis*, *Gypidula comis*, *Stringocephalus burtoni*, *Kefersteinia subovata*, and *Paracyclas antiqua*.

The Manitoban or upper Devonian formation is exposed in several cliffs and points to the north of the mouth of Steep Rock river within a few miles. One of the best sections is exposed at Point Wilkins. Point Wilkins, which

is four miles (6·4 km.) north of Steep Rock river, rises 80 feet (24 m.) above the lake. The cliffs here expose the following beds of the Manitoban formation:—

b. Light grey, fine grained, thin-bedded limestone, some beds breaking with conchoidal fracture, 45 ft. (13·7 m.)

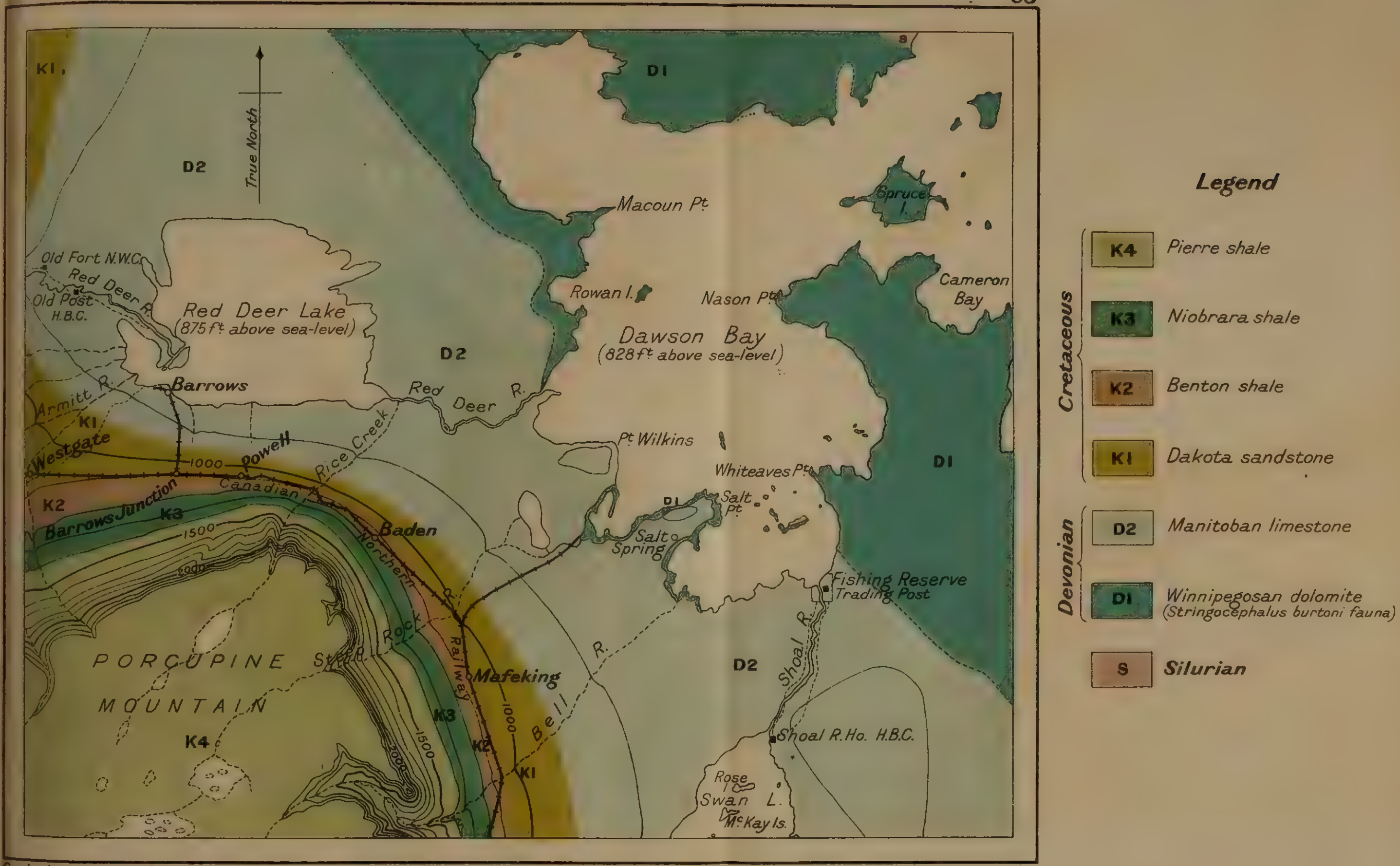
a. Light ash grey, argillaceous limestone 35 ft. (10·6 m.)

The species which are most abundant in the lower beds (b) are *Atrypa reticularis* and *Paracyclas elliptica*. The upper beds contain a very sparse fauna, in which *Athyris vitata* is one of the most abundant species. *Stringocephalus burtoni* and many of the other fossils of the Winnipegosan dolomite are unknown in this upper formation.

An interesting feature of the Point Wilkins section is the brecciated beds which appear very near the southern end of the cliff. Here, where the cliff has a height of only about 25 feet (7·6 m.), the horizontal and undisturbed limestones pass abruptly into a belt of limestone which has been broken into large angular blocks; these have been more or less completely recemented together. Some of the interspaces are filled with a light grey micaceous sandstone. There are no Devonian beds in any part of the section which resemble this sandstone filling. It probably represents material which sifted into the interstices of the breccia during the deposition of the Dakota formation of the Cretaceous, which further westward overlies the Devonian limestone.

Immediately south of the Point Wilkins cliffs, and a few rods from the brecciated limestone an old forest-covered beach of comparatively recent date rises about 15 feet (4·5 m.) above the surface of the lake. Another and much older beach or bar 6 to 8 feet (1·8 to 2·4 m.) high extends across the top of the cliff 100 to 200 yards (91 to 182 m.) back of its face. This beach stands about 85 feet (26 m.) above the level of the lake. The present high stage of the lake is indicated by the line of dead birches now standing on the edge of the lake along the foot of the Point Wilkins cliff on the northeast side.

Numerous salt springs issue from the Devonian limestone at various points along the streams entering the west side of Dawson bay. North of the mouth of Bell river, two and three quarter miles (4·4 km.), a small brook enters the lake which is estimated to discharge into the lake $37\frac{1}{2}$ tons of salt every 24 hours [**4.**]. The salt beds thus indicated in the Devonian are known only through the saline springs.



Geological Survey, Canada.

Dawson Bay

Miles
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Kilometres
5 0 5 10 15 20 25

ANNOTATED GUIDE.

(Dauphin to Winnipeg.)

Miles and Kilometres from Winnipeg

177·8 m. 286 km. **Dauphin**—Altitude 957 ft. (287 m.). Dauphin lies about 177 miles (286 km.) northwest of Winnipeg, and is situated just to the east of the first prairie escarpment which marks the boundary between the flat floored valley of glacial Lake Agassiz and the second prairie steppe. This escarpment, in its southern extension to the southwest of Ochre, is known as Riding mountains, and continues northwards under the name of Duck and Porcupine mountains, the three groups being separated by the cross valleys of Valley and Swan rivers. The escarpment has been formed by aqueous erosion of the almost horizontal Cretaceous rocks overlying the Palæozoic which forms the major portion of the bed rock floor of Lake Agassiz.

Between Dauphin and Winnipeg the railway crosses the following series. From Dauphin to Ochre the road is underlain by the Dakota series, succeeded by Devonian limestone which extends to Makinak. Between Makinak and Laurier the railway again crosses the Dakota and the approximate contact between the Benton and Dakota is about six miles (9·6 km.) north of McCreary. Between McCreary and Gladstone the country is underlain by the Benton shales, succeeded at the latter point by the Dakota sandstone, the lowest series of the Cretaceous, which extends as far as Beaver. From Beaver to Portage la Prairie the underlying rock is Devonian. East of Oakville toward White Plains the country is underlain by the Silurian, no outcrops, however, occurring adjacent to the railway.

140 m. 225 km. **McCreary**—

92·6 m. 149 km. **Gladstone**—

55·5 m. 89 km. **Portage la Prairie**—

From Headingly to Winnipeg, the underlying rock is Ordovician limestone and shales.

0 m. 0 km. **Winnipeg**—Altitude 761 ft. (232 m.).

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WINNIPEG TO PORT ARTHUR.

BY

A. L. Parsons.

ANNOTATED GUIDE.

(Winnipeg to Kenora).

Miles and Kilometres.

0 m.
0 km.

Winnipeg—Altitude 757 ft. (230·7 m.). The level, treeless prairie at Winnipeg, representing the former bed of glacial Lake Agassiz, extends eastward along the Canadian Pacific railway to Darwin. In this distance, however it gradually changes to a somewhat rolling, heavily forested country and, eventually, at Darwin, gives place to the hummocky, glaciated

Miles and Kilometres.

rock surface of the Pre-Cambrian shield. The underlying Ordovician limestone is hidded except at Tyndall and Garson, where quarries may be seen at some distance from the railway.

69·5 m. 101·8 km. **Darwin**—Altitude 972 ft. (296·3 m.). From Darwin to Summit, a total distance of 340 miles (547 km.), the route crosses a region underlain by alternating stretches of Keewatin schists and Laurentian granite-gneisses that present no points of particular interest. The solid rocks are covered more heavily than usual with boulder clay and stratified clays, and consequently the topographic relief is even less than in most parts of the Pre-Cambrian shield. Rock-bound lakes are very numerous.

132·7 m. 213·5 km. **Kenora**—Altitude 1,088 ft. (331·6 m.). The Keewatin-Laurentian contact lies not far to the north of the railway in the vicinity of Keewatin and Kenora. In consequence of this, the Keewatin schists have been contact-metamorphosed into highly crystalline hornblende schists and gneisses.

A fine view of Lake of the Woods is obtained just as Kenora is entered. This town, the largest between Winnipeg and Fort William, is the business centre for mining, lumbering and milling industries in the Lake of the Woods district.

PRE-CAMBRIAN GEOLOGY IN THE NORTHERN PART OF LAKE OF THE WOODS.

General Geology of the Region.

The northern part of the Lake of the Woods is characterized by rocky shores, numerous islands and a rugged topography, though the elevation of the highest hills above the level of the lake is seldom more than 150 feet (45 m.). Though most of the islands and the main shore are covered with a dense forest growth, principally of second growth spruce, jack pine (P. banksiana), and birch, there is as a rule not a great depth of soil overlying the rock, which can be seen almost

continuously along the shores. The rugged relief of this northern part of the lake is in decided contrast to the region south of Grande Presqu'ile, where many sandy beaches and dunes and high rocky shores are uncommon.

According to Dr. A. C. Lawson (**1**), to whom our geological knowledge of this district is chiefly due, the Pre-Cambrian rocks are separable into four principal groups: Keewatin; Laurentian; a series of granites younger than the Laurentian; and Keweenawan.

KEEWATIN.

The oldest of these formations, the Keewatin, is divided for purposes of mapping into four divisions which appear to be lithologically distinct, but at times grade so imperceptibly from one to another that it is well nigh impossible to draw hard and fast boundaries. These are:—

(a) Hydromicaceous schists and nacreous schists, with some associated chloritic schists and micaceous schists, and including areas of altered quartz porphyry.

(b) Clay slate, mica schist and quartzite, with some fine grained gneiss.

(c) Agglomerates and other coarse clastic rocks, all more or less schistose and generally of volcanic origin.

(d) Hornblende schist and altered trap, with some chlorite schists of volcanic origin.

In addition to the above, some bands of carbonaceous schists and ferruginous dolomite and possibly some serpentine are included in the Keewatin.

Of the four principal divisions the last two are definitely referred by Dr. Lawson to an irruptive origin; the first is said to have been laid down by sedimentation, though probably originally volcanic, and the second is assumed to be of a sedimentary origin.

Hydromica Schists, Nacreous Schists, etc.—Dr. Lawson seems to consider that the members of this sub-group are largely sedimentary, though originally volcanic (volcanic ash beds). He recognizes quartz porphyry as the original rock from which part of the series was derived. The writer's study would indicate that they resulted largely from the alteration of a diorite or andesite similar to the more acidic portions of the ellipsoidal trap. In the development of these schists, the rock passes through a stage which has been called agglomerate, though this term

is made to include two classes of rock, friction breccias or autoclastic rocks and volcanic breccias formed where a dark lava has intruded the older lavas. The friction breccia is the common intermediate stage in the development of the sericite schists. These schists with the breccia agglomerate are shown on the unnamed island west of Queer island, also upon Slate island in the vicinity of a Keweenawan dyke.

A marked feature of these schists is the prevalence of ferro-dolomite or ankerite, which in some cases forms vein-like masses as much as 20 feet (6 m.) in width. As a rule this material is not pure, but contains streaks of sericite or chlorite and some quartz. Its weathered surface is ochre yellow and of striking appearance. Good examples of ferro-dolomite can be seen on a small island east of Pipestone point and north of Square island, on the mainland east of Square island, and on an island east of Whiskey island. Another conspicuous band of this material is shown on the west side of Middle island.

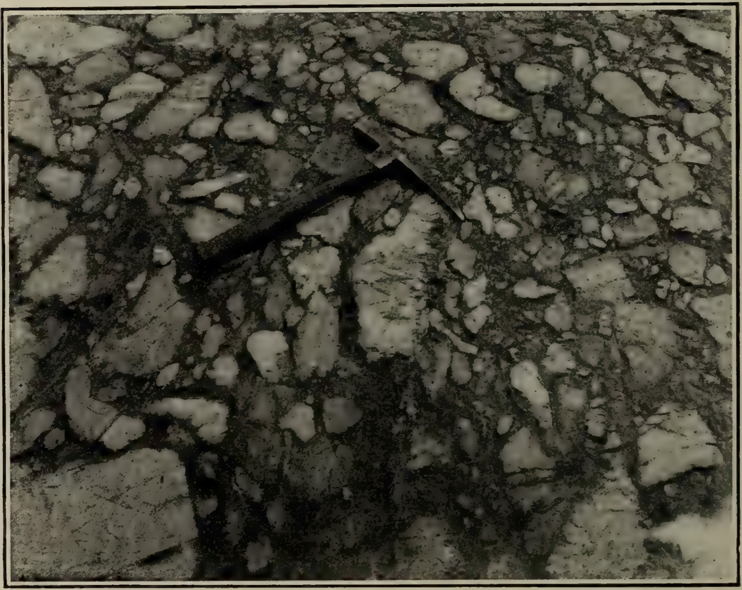
Clay Slates, etc.—This subdivision consists principally of highly altered hornblende and biotite schists which may or may not contain garnet. In some instances true slate has been found, but this is only in small quantity. In regard to making a distinct division of the Keewatin to include these rocks there is considerable diversity of opinion. It may be said, however, that they have been found principally in close proximity to Laurentian masses or to the later (?) granites and there seems to be no objection to considering them merely as highly altered phases of the ordinary Keewatin traps. In numerous instances this rock contains large veins of pyrrhotite which have been prospected for gold, but as a rule these deposits have been found to be of no economic value.

In certain places on West Hawk lake these highly altered rocks (**7**, p. 202) seem to be of sedimentary origin, but so far as partial analyses of rock from Lake of the Woods show (**7**, p. 179), the rocks of this subdivision found there are probably of igneous origin.

This highly altered rock outcrops near Keewatin and Norman. It underlies the town of Kenora and continues thence in a northeasterly direction for about six miles (9·6 km.).

Agglomerate.—Under this title are grouped fragmental rocks of extremely varied texture and origin. The more

common type of agglomerate appears to be merely a brecciated Keewatin trap or andesite which grades into sericite schist. This rock is usually light coloured, and is well developed near the Keweenawan dyke on the unnamed island west of Queer island. Through a cartographic error this outcrop was shown on the older maps as clay slate.



Agglomerate; Kenora, Ont.

The other principal type of agglomerate is also a breccia, but in this case the brecciation is probably caused by a flow of dark lava which has broken off fragments of solid rock and cemented them together. It is possible, however, that this type is due to the falling of volcanic bombs and ash into molten lava, though the gradation from the ellipsoidal trap to agglomerate on the east side of Ash bay would strengthen the former suggestion. This type of agglomerate is well exposed near the old saw-mill in Kenora.

Altered Traps, Hornblende Schists and Chlorite Schists.—These rocks, which are by far the most widely distributed of the Keewatin rocks in this region, are probably all of the same origin. In general it may be said that

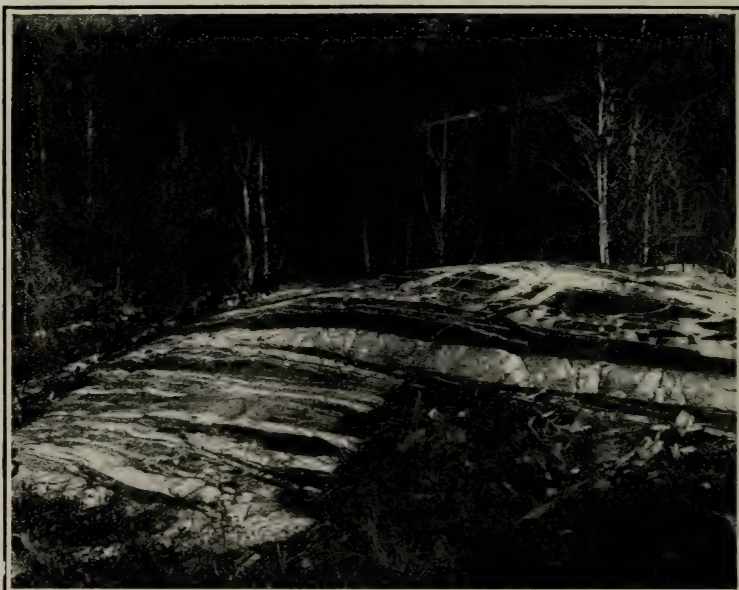
these ancient traps are diorites (or diabases in some instances) with an ellipsoidal or pillow structure. In places that have been badly weathered, this structure is sometimes obscured, but careful search will usually reveal it even when the trap has been largely altered to chlorite schist. The ellipses usually consist of a light coloured

Contact breccia, Keewatin and Laurentian. Barry lake.

interior and an outer band of dark material which appears to be a basic segregation, though both portions can be classed as diorite. In the interstices between the ellipses is a filling of ferro-dolomite or ankerite with some quartz and frequently a considerable quantity of epidote. Rocks of this character are particularly well shown at Devil's Gap and on the west side of Big Stone bay from the Keewatin mine to Eagle passage. In these places the typical ellipsoidal structure is well developed. In other places the squeezing of these ellipses in the alteration of the rock to chlorite schist and in certain instances to sericite schist is beautifully shown.

At the contact of the Keewatin with the Laurentian there is found usually, if not always, a hornblendic rock

which is considerably brecciated and evidently resulted by recrystallization of the ancient traps. This type of material is to be seen near the Sultana mine and on the west side of Bottle bay, where domes of granite show nearly every possible phase of this rock from the slightly altered trap with pillow structure to the brecciated hornblendic rock



Brecciated contact, Keewatin and granite. Sultana mine.

included in domes of granite. Sometimes even the granite domes are free from it except near their margins. To the west of the small indentation on the north side of Andrew bay, several of these granite domes, with the brecciated hornblendic rock grading into the ancient traps, are to be found. These domes have the typical "roches moutonnées" structure and have evidently been denuded by glaciation, but it is of interest to note that the resultant form has been determined not by the ice but by the original intrusion of the granite. Examples of this structure are extremely common in other parts of Lake of the Woods particularly along the shore of Grande Presqu'ile. These however are beyond the limit of the excursion.

LAURENTIAN.

The Laurentian formation in the Lake of the Woods region is represented by large areas of granite and gneiss. This group is almost entirely lacking on the shores of the northern part of the lake, though there are several granite outcrops which may belong to it but have been referred to a later period by Dr. Lawson. If, however, the trap dykes, which are elsewhere described, are to be assigned to the Keweenawan it will probably be necessary to refer part of this granite, to which a later origin has been assigned, to the Laurentian. This would apply to the outcrop on Micrometer island, where the trap cuts the granite, and it would probably apply to all the granite in the northern part of the lake.

Typical Laurentian granites and gneisses are to be seen from the train on the Canadian Pacific railway at Margach (formerly Rossland) and west of Darlington bay near Keewatin. In the present excursion no outcrop of unquestioned Laurentian rock is visited, though probably the granite at the Sultana mine is to be so classed. There is an extensive development of rocks of this age north of Kenora and in the region to the east of Route bay. The most interesting area, however, from many points of view is the Grande Presqu'ile, which is essentially a series of domes of granite and gneiss with margins of highly altered Keewatin trap, and may be compared with the granite outcrops on the north side of Andrew bay and on the west side of Bottle bay. In the Andrew bay outcrops the granite protrudes through the surrounding traps in large dome-like masses which, near the contact with the trap, contain numerous fragments of re-crystallized trap, while at Bottle bay some of the domes are overlain by arched masses of the older trap, and others are like those to the north of Andrew bay.

The character of those granite masses can probably be best studied near the Sultana and Ophir mines. There the texture varies from that of a coarse granite porphyry to a granitic and even microgranitic texture. Near the contact with Keewatin traps there are places where it is difficult to distinguish the two rocks, as both are fine grained and have possibly undergone an interchange of material which seems to furnish a gradation between them. This however, is not the usual case; ordinarily the contact

is a brecciated one of no great width, the Laurentian is granitoid and the adjoining Keewatin is a dark finely crystalline hornblende schist or diorite.

LATER GRANITE.

Several of the above mentioned outcrops of granite, supposed to be later than the Lauientian, have been minutely described by Dr. Lawson, but the distinctive characters by which they may be distinguished from the Laurentian granites are apparently lacking in the exposures to be visited.

KEWEENAWAN.

A remarkable series of dykes crosses Lake of the Woods and Shoal lake in a general northwest and southeast direction. The continuation of some of these in Rainy Lake region gives a length of about 100 miles (161 km.) to some of the better developed dykes.

These dykes are essentially a coarse grained quartz diabase with a porphyritic border. In the original description (**2**), garnet is mentioned as one of the prominent minerals in the central portion, but this has not been found in the material secured by the writer from outcrops of Lake of the Woods. The other minerals observed as well as the characteristic texture of the rock, agree with the description given by Dr. Lawson. In the northern part of Lake of the Woods four of these dykes are known, while in Welcome channel a fifth dyke, that has been altered to serpentine, may possibly upon further study be correlated with these.

The adjacent Keewatin rocks usually show marked metamorphism for 20 to 30 feet (6 to 9 m.) away from the dykes. This is more evident in sericite schists containing ferro-dolomite, though is is also to be observed in the chloritic schists. As a result of this metamorphism the schists are crumpled, and epidote, magnetite and hematite, which are readily noticed in the field, are formed.

The most accessible of these dykes is that which was mapped on Thompson island and Whitefish bay. It has been traced almost without interruption from Darlington bay to the east side of Whitefish bay, and is apparently continuous with a dyke on Crow lake. In places, as on

Allie island, the rock is much decomposed, giving a chloritic or serpentinous mass in which native copper is found, though this material has not been observed in the unaltered rock.

Gold Mines of the District.

For about thirty years the region around Lake of the Woods has attracted more or less attention on account of discoveries of gold, and mining has been carried on with varying degrees of success. Several very rich pockets have been found, and gold to the amount of about two million dollars has been recovered from the mines on this lake and Shoal lake. At the present time there is little activity, though the Cameron Island mine and the Canadian Homestake mine are developing on low grade ore.

The best known mines of this region are: the Mikado, with a reported production of about half a million dollars; The Regina or Black Eagle mine, with a production about equal to that of the Mikado; and the Sultana mine, with a production estimated between seven hundred thousand and a million dollars. At the time of writing none of these mines are being worked. In all three the veins fill fissures which cut across the contact between granite and Keewatin traps. The vein material is largely quartz, but with this is a large quantity of ferro-dolomite which weathers to a rusty brown on exposure to the atmosphere.

Itinerary.

The following itinerary has been selected to show characteristic examples of the different formations described by Dr. Lawson. Two minor formations, the carbonaceous schists and the serpentine, are omitted, as they are too far distant to be reached in a trip of one day.

At the long pier near the residence of Captain H. A. C. Machin is a remarkably fine outcrop of agglomerate which shows large fragments of acidic rock in a paste of darker, more basic rock. It has been supposed by some that this is a conglomerate of water-worn pebbles and boulders, but, although there is no apparent means of determining the origin of this rock at this place, its derivation is well shown in the neighbourhood of Ash bay as probably being from a volcanic breccia.

Leaving the agglomerate the route lies through the beautiful islanded part of Lake of the Woods which extends for about 10 miles (16 km.) from Kenora. On the mainland is a large brick school devoted to the education of Indians, while the cottages of the summer residents are to be seen on nearly every island. A narrow channel, known

The Devil's Gap.

as Devil's Gap, separates Rat Portage bay from the main part of the lake, and in passing through it the peculiar landmark which gives this channel its name is seen on the left. The rock along the shores is the characteristic ellipsoidal trap of the Keewatin, though the ellipses are not so marked as some that are to be seen later. Although showing a well preserved elliptical structure, all these rocks when broken exhibit a schistose structure. On a small island on the left of the channel is an outcrop of felsite which is probably connected with the Laurentian.

On the mainland to the left is an exposure of trap which has been referred to a later age by Dr. Lawson. This trap is so distinct in appearance from the other later traps and so similar to the recrystallized traps in contact with

the Laurentian granite that it seems doubtful whether it is not merely a highly metamorphosed Keewatin trap. Strength is give to this supposition by the proximity to the felsite just mentioned and to the granite to be seen a little later on the mainland. The dome-like outline of the outcrop is also suggestive of the granite domes to be seen in Bottle bay.

A good view of the Manitou stretch to the right gives an idea of the large, open portions of the lake, while to the left the protected waters of Matheson bay are to be seen. All the mainland between Devil's Gap and the Sultana mine is an Indian reserve, and here is a forest growth of Norway and white pine that has not been affected by lumbering operations. Here also is an Indian village with its characteristic primitive construction in effective contrast with that of a modern house that stands in the same village. Various types of tepees or wigwams are to be seen, though the covering may be lacking, as it is customary nowadays to cover the frames with canvas. The frames, consisting of four inclined poles meeting at a point with horizontal cross poles, were used in smoking and drying of meat.

Just beyond the Indian village lies Bare point, where the darker traps give place to an exposure of sericite schist which may be traced along the shore for about two miles (3·2 km.). This outcrop however is not easily accessible in a launch. At Quarry island the rock changes to a granite of the same character as that at the Sultana and Ophir mines.

From the Sultana mine a walk of about a mile affords an opportunity of studying the contact of the granite with the Keewatin. Three hundred feet (91 m.) north of the landing is a pyrrhotite vein about 10 feet (3 m.). wide, in what appears to be a quartz porphyry. The old dumps and the mill furnish interesting material for study.

Following a trail from the Sultana mine, the contact between the granite and the Keewatin and the gradation from a fine grained granite to a coarse granite porphyry may be observed. From the summit of the hill above the Sultana mine a comprehensive view of the northern part of the lake is obtained. On reaching the Ophir mine comparatively unaltered specimens of the granite porphyry may be secured on the dump, where it is also possible to find specimens of quartz showing free gold.

In a southeasterly direction from the Ophir dock beyond a fishing station and the south end of Sultana island is Needle point, where the ancient traps have been so altered that nearly all trace of their original structure has been lost and they appear as hornblendic and chloritic schists. Just beyond this point is the old Keewatin mine,

Ellipsoidal trap. Shoal lake.

where the ellipsoidal character of the trap is well shown as the result of the weathering out of the interstitial material. These ellipsoids, when fresh, are usually light coloured in the middle and dark on the borders, while the interstices are filled with quartz, ferro-dolomite and epidote. Usually the interstitial material is lacking on the weathered surfaces.

At the south side of Big Stone bay southeast from the Keewatin series, some of the precipitous outcrops of trap show the ellipsoidal structure with the accompanying ferro-dolomite. The best examples lie between high and low water marks.

Continuing along the south shore of Big Stone bay the route lies through Eagle passage and thence in a south-

westerly direction to Pipestone point, where sericite schist is prominently developed, likewise an abundance of ferruginous carbonate which in some cases is abundant enough to suggest a low grade iron ore. Such an outcrop is found on a small island just east of this point, where apparently it has resulted from the alteration of a Keewatin

Metamorphosed sericite schist; Slate island, Lake of the Woods.

porphyry. Another outcrop of this same material occurs on the mainland east of Square island.

Crosssing Andrew bay from this place a peculiar tepee made of split logs and covered with brush and earth may be seen near the entrance to Bottle bay. Entering Bottle bay the rock is a breccia agglomerate passing into sericite schist. This is followed by darker traps (on the west side). some of which are recrystallized and folded over granite bosses. Farther south the granite bosses are to be observed without the covering of trap, but occasionally a contact breccia is seen where the granite has intruded the trap. These bosses are in the form of 'roches moutonnées' and have undoubtedly been subjected to severe glacial action, but the factor determining the resultant form is apparently

the original shape of the granite boss rather than glacial action.

On the unnamed island just west of Queer island a trap dyke of probable Keweenawan age cuts an agglomeratic sericite schist. Specimens of this rock, showing the fine grained porphyritic material near the edges and the coarse diabase near the centre, are readily obtained, but it is difficult to get good contact specimens. These latter however may be secured on Slate island, where the same dyke cuts the same type of country rock, and a contorted metamorphosed zone about 30 feet (9 m.) wide is present. This metamorphosed rock closely resembles the rocks mapped as clay slate, etc., but the adjoining unaltered rock is sericite schist and agglomerate containing an abundance of carbonates. It is again seen at the contact of the same dyke on Thompson island, though the adjoining rock retains the ellipsoidal structure to a greater extent than on Slate island. Leaving Thompson island the route lies through the Keewatin channel to the north side of Rat Portage bay (on mining location K. 85), where highly altered Keewatin rocks mapped as clay slates, etc., are well developed on the shore. These are principally hornblende and biotite schists, in some places containing an abundance of garnets and intersected by large veins of pyrrhotite. These rocks are principally developed near the contact with the Laurentian granites.

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ANNOTATED GUIDE.

Miles and Kilometres.

188·3 m. 302·7 km. **Vermilion**—Alt. 1221 ft. (372·2 m.). Eagle lake another large example of the rock-bound lakes so characteristic of Pre-Cambrian regions, is seen at Vermilion. Gold is mined in the Keewatin schists at several points on this lake.

214·9 m. 345·8 km. **Dryden**—Alt. 1220 ft. (371·8 m.). Between Minnitaki and Wabigoon the Pleistocene deposits, either of boulder clay or of stratified clay, are unusually thick and support a scattered farming community. At Dryden the stratified clay is used also for brick making. Gold mines, including the Laurentian mine, are located at a number of points in the country to the south and southeast of Dryden, but none of these are near the railway.

277·9 m. 448·4 km. **Ignace**—Alt. 1487 ft. (453·2 m.).

385·9 m. 621·1 km. **Buda**—Alt. 1472 ft. (448·7 m.).

Keewatin volcanics and their schistose equivalents are continuous from near Buda to the neighbourhood of Summit, where they are unconformably overlain by flatlying Animikie sediments. But from this station to Port Arthur, a distance of 18 miles (29·0 km.), the railway traverses a flat delta plain terminating at Lake Superior, and rock exposures are infrequent. In places a red soil has been formed by weathering of Animikie iron formation, where that formation lies at no great depth. Although there are no outcrops near the railway, the horizontal Animikie sediments and the Keweenawan diabase sills intrusive into them

Miles and Kilometres.

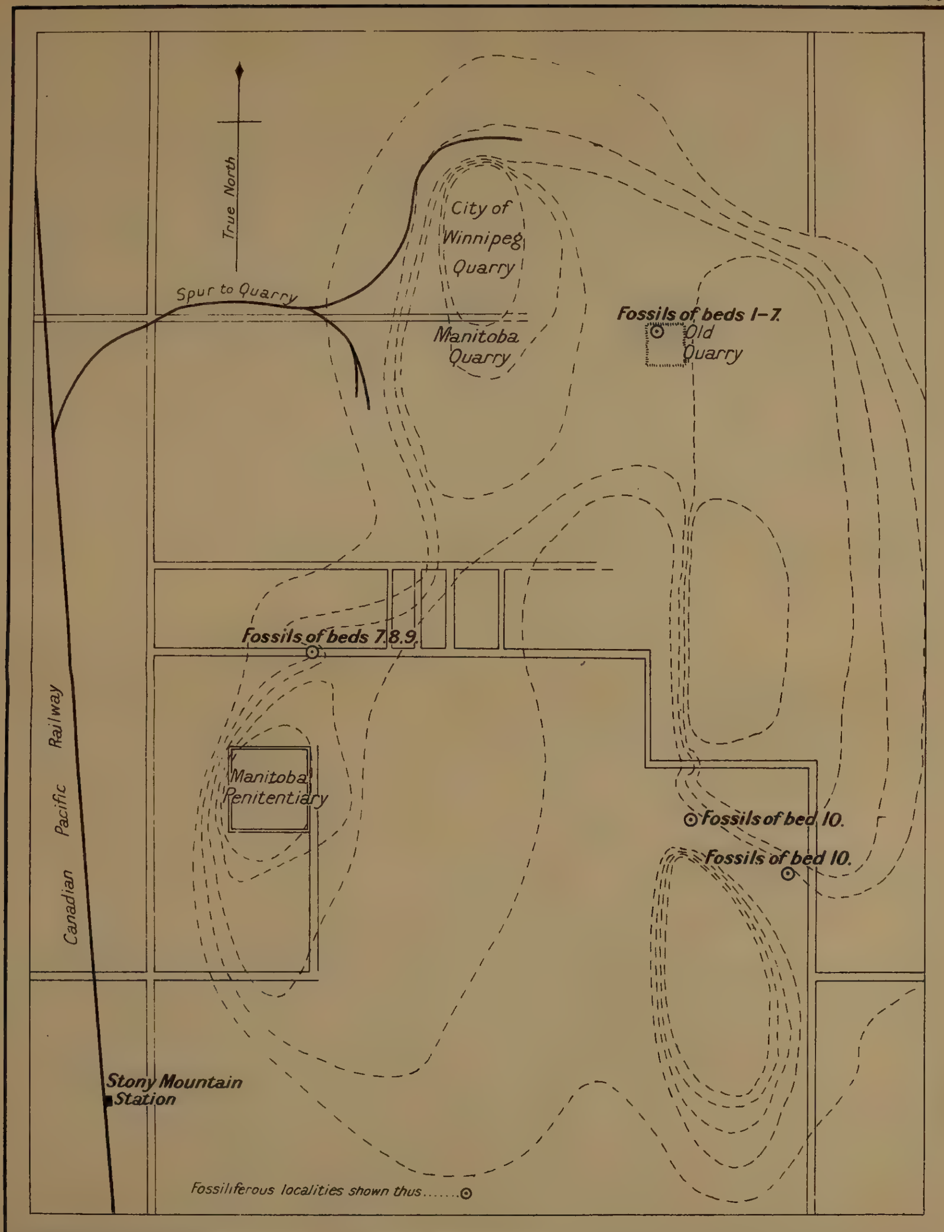
form peculiar flat-topped hills not far to the south. These mesa-like hills are capped by portions of the horizontal sills, which resist erosion better than the slates. Mount McKay, which is seen to the south as Fort William is entered, is a splendid example of this type of topography.

426·3 m. 686·2 km. **Fort William**—Alt. 607 ft. (189. m.).

430·6 m. 693·1 km. **Port Arthur**—Alt. 608 ft. (189·3 m.). Lake Superior is in sight all the way between these towns.

PORT ARTHUR TO TORONTO.

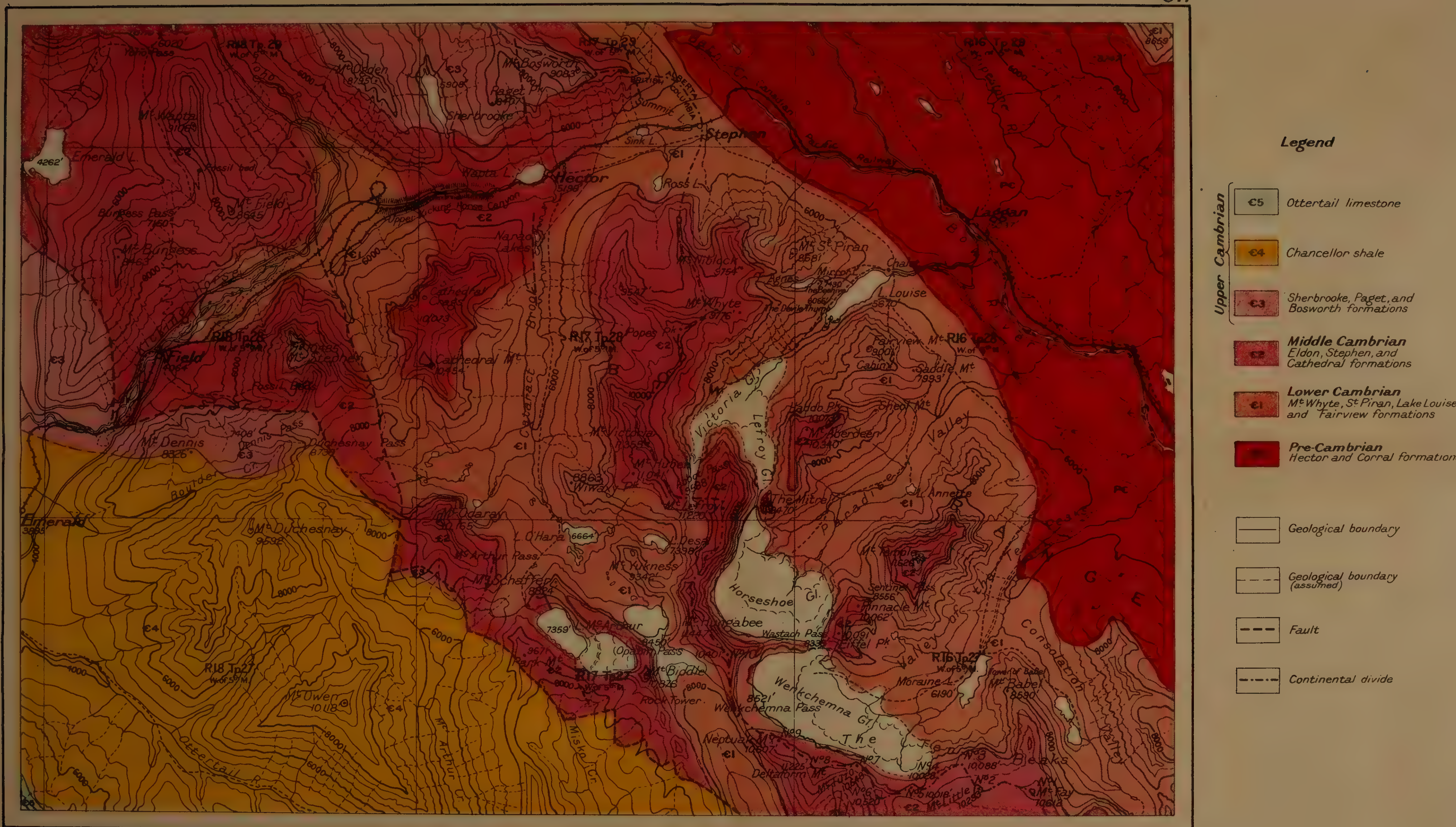
From Port Arthur to Toronto the excursion follows the same route as that taken in the west-bound journey, a guide to which is found on pages 13 to 36 of this Guide Book and in Guide Book No. 6.



Geological Survey, Canada

Stony Mountain

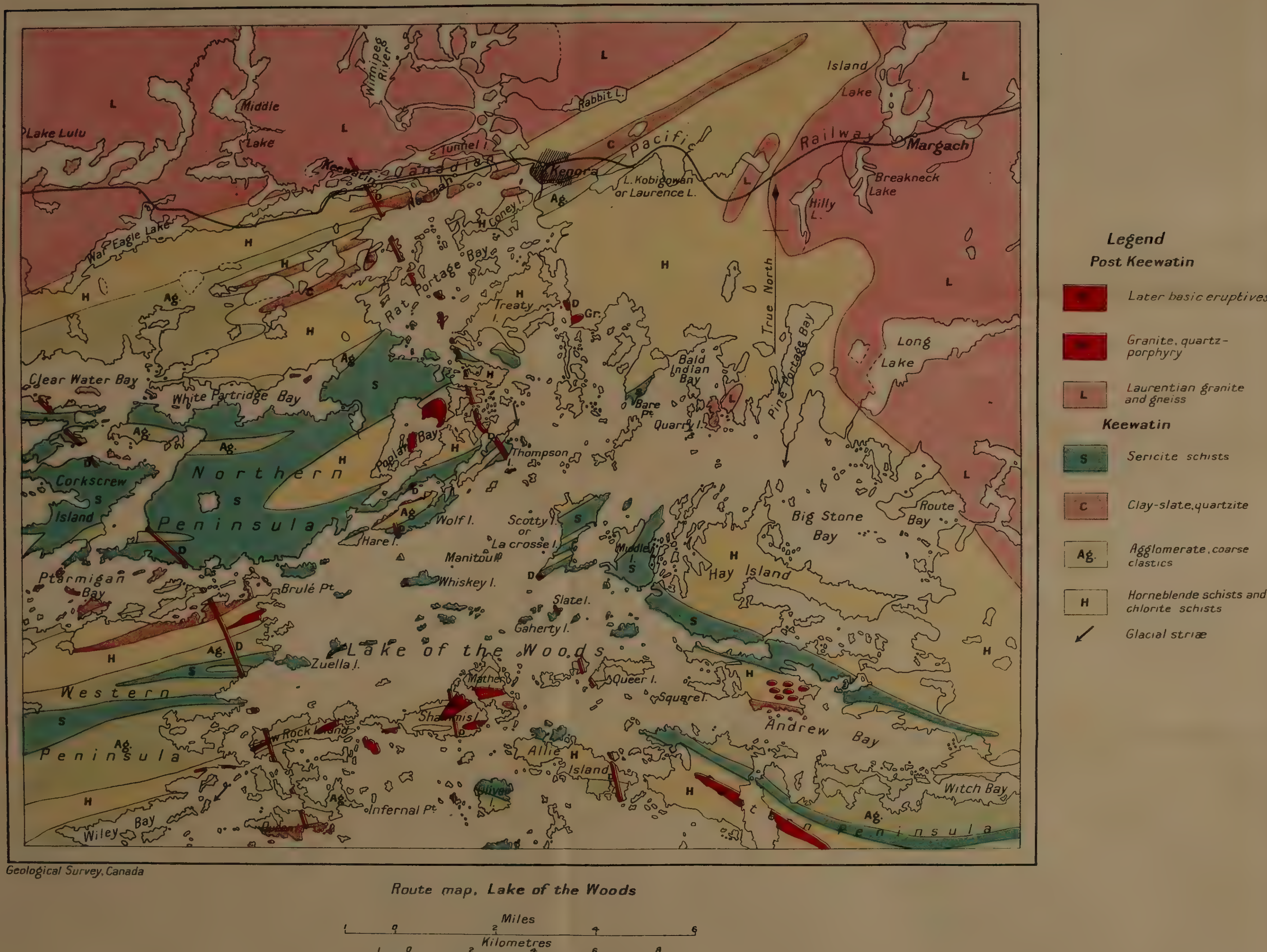
Cl.



Geological Survey, Canada.

Laggan — Field

Miles
1 ½ 0 1 2 3 4 5 6
Kilometres
1 ½ 0 1 2 3 4 5 6 7 8 9 10



Route map, Lake of the Woods

C1.

Geological Survey, Canada.

Glacier

Miles
1 ½ 0 1 2 3 4 5

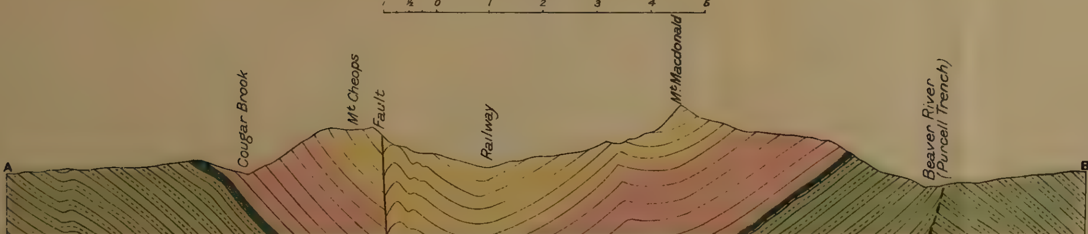
Kilometres
1 ½ 0 1 2 3 4 5

Legend

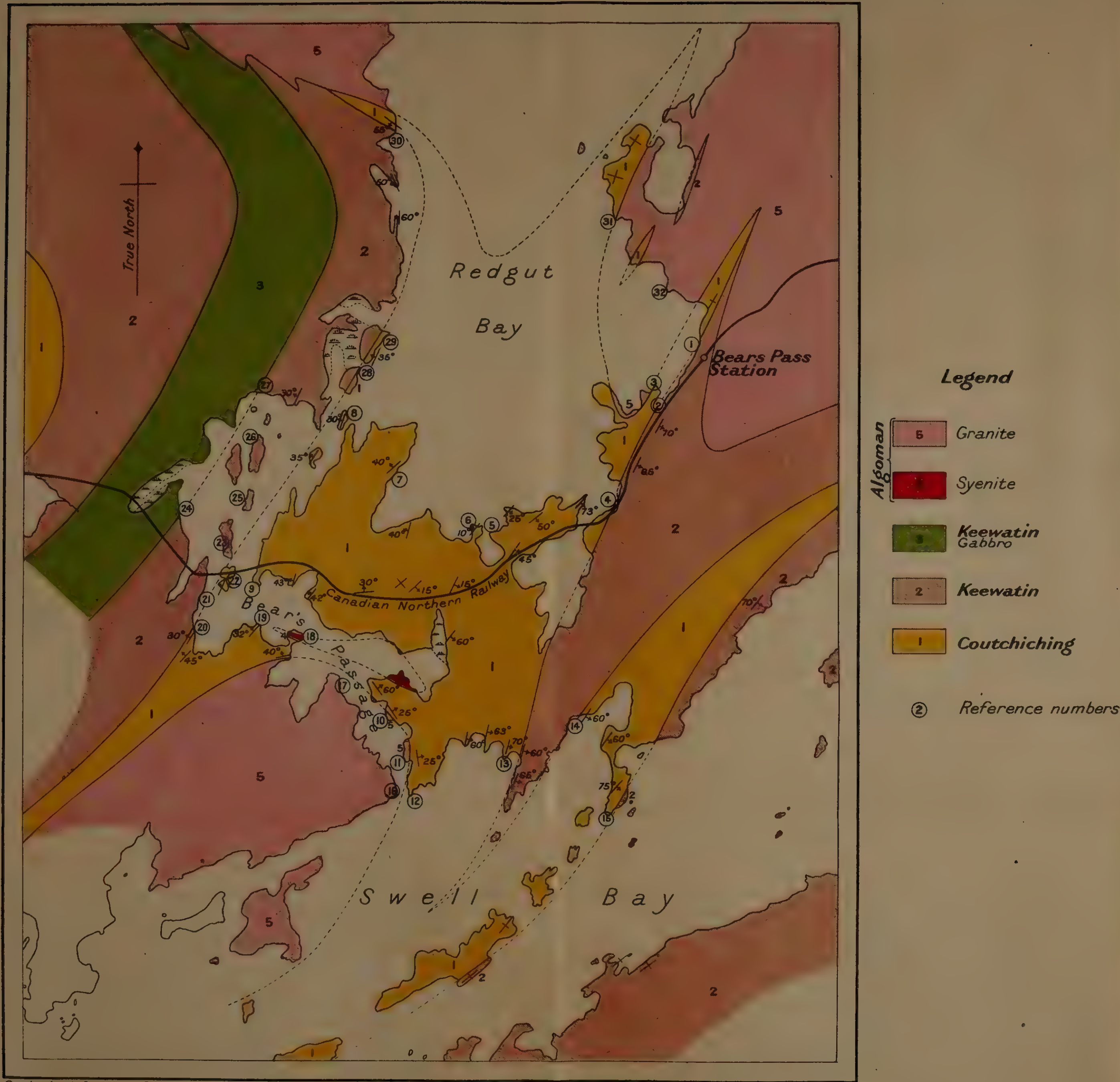
- Glacier and snow-field
- **Sd** Sir Donald quartzite
- **R** Ross quartzite
- Nakimu limestone
- Nakimu limestone (mapped approximately)
- **C** Cougar formation (quartzite, metargillite)
- **Am** Phyllitic metargillite Youngest member of Albert Canyon division of Selkirk series

Beltian

Note--Faults not shown on the map



Section along line AB



Geological Survey, Canada.

Bears Passage, Rainy Lake

Miles 1 ¾ ½ ¼ 0 1 2

Kilometres 1 ¾ ½ ¼ 0 1 2 3 4

Geological Survey, Canada.

Victoria and Vicinity

Miles: 1 ¾ ½ ¼ 0 1 2 3

Kilometres: 1 ¾ ½ ¼ 0 1 2 3 4 5

C7.

Geological Survey, Canada

Route map between **Victoria** and **Nanaimo**

Miles: 1 0 5 10 15

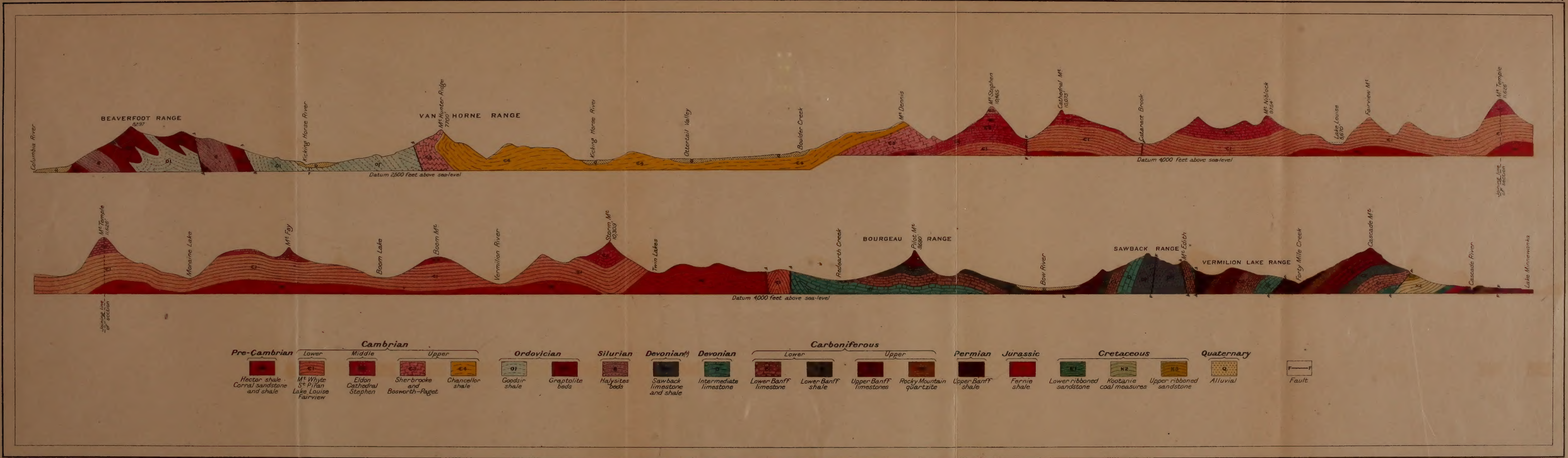
Kilometres: 1 0 5 10 15 20

Geological Survey, Canada

Structure Section of the Selkirk and Purcell Mountains from Moberly Peak to Revelstoke

Horizontal and Vertical scale
Miles
Kilometres

Cl.



Geological Survey, Canada.

Structure Section** across the **Rocky Mountains** near the **Main Line** of the **Canadian Pacific Railway** between the **Cascade Trough** and the **Columbia Valley

Horizontal and Vertical scale

Miles

Kilometres


MAP OF
COBALT AREA
DISTRICT OF NIPISSING
Showing Veins & Location of Sections
To accompany Fourth Edition of Report by
Willet G. Miller, Provincial Geologist,
On the Cobalt-Nickel-Arsenides and Silver Deposits of Temiskaming,
in Part II. of the Nineteenth Report of the Bureau of Mines, Ontario.
Hon. F. Cochrane, Minister of Lands, Forests and Mines.
SCALE: 1/9600 800 Feet to an Inch.
FEET
LEGEND
GLACIAL AND RECENT
PRE-CAMBRIAN
NIPISSING Diabase
Igneous Contact
COBALT series, together with small outcrops of TEMISKAMING series near south end of Cross Lake.
LORRAIN Granite, intrusive into Temiskaming series but not into Cobalt series.
Igneous Contact
KEEWATIN series, Igneous complex (Greenstones, etc.)
Productive Veins
Road
Shaft
Mines that have been or are producing.
Section Lines
NOTES
The colored cross-sections, the positions of which are indicated by blue lines on this map, accompany the 4th edition of the report.
The granite dike on the University property is a differentiation product of the diabase magma.
COBALT LAKE
KERR LAKE
CROSS LAKE
PETERSON LAKE
GIROUX LAKE
CART LAKE
SASAGINAGA LAKE
SHORT LAKE
BRADY LAKE
NOVA SCOTIA
COBALT CENTRAL
HUDSON BAY
NIPISSING
TRETHEWEY
COBALT CENTRAL
BUFFALO
TOWN SITE MG. CO.
SILVER QUEEN
McKINLEY-DARRACH
LITTLE NIPISSING
KERRY
STANTHONY
UNION PACIFIC
VIOLET (LA ROSE)
COLONIAL
SILVER CLIFF
SILVER LODE
VICTORIA
WATTS
REINHARDT
MICHAEL
TRINITY COBALT
AIRGIOD
RELIANCE
FARAH
PONTIAC
COLEMAN
IMPERIAL CROWN
SILVER CROSS
DRUMMOND
SILVER LEAF
CROWN RESERVE
COBALT PROVINCIAL MINE
SAVAGE
SILVER BAR
ALEXANDRA
BAILEY COBALT
FOSTER
LAWSON (LA ROSE)
KERR LAKE MG. CO.
ARGENTUM
POWELL
SILVER MOUNTAIN
McCORMACK
WYANDOH
CLEOPATRA
UNIVERSITY (LA ROSE)
HARGRAVE
EASTBOURNE
COBALT MERGER
DAVIS
NUGGET
SILVER HILL (LA ROSE CONSOLIDATED)
BADGER
BEAVER
GILLIES
DREADNOUGHT
WALDMAN
ROCHESTER
CALUMET
PAN SILVER
COBALT CENTRAL
TEMISKAMING
LARGE
BELMONT
GREAT NORTHERN
COBALT SILVER HILLS
WATASH
COBALT BLUE
CRYSTAL SILVER
CHAMBERS FERLAND
LA ROSE
MONARCH
PAYMASTER
GOULD CONSOLIDATED
WALDMAN